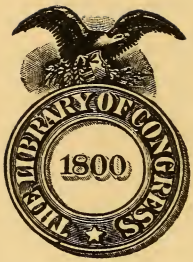
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1800

CHEMISTRY FOR BEGINNERS:

WITH ENGRAVINGS.

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HARTFORD:
PUBLISHED BY F. J. HUNTINGTON.
1834.

Entered according to Act of Congress, in the year 1834, by
F. J. HUNTINGTON,
in the Clerk's Office of the District Court of Connecticut.

2055

J. S. and C. Adams, Printers, Amherst, Ms.

PREFACE.

The design of this work is to teach Chemistry to beginners. The author has sought to present the elements of the science in a popular and attractive form, without offending the scholar by marring its classical beauty and proportions. It is difficult for the experienced chemist, to whom the technicalities of the science are familiar as the most common terms, to bear in mind that to the beginner, they are as the words of an unknown tongue; and that it is not principles alone that he must be taught, but the very language in which these principles are to be expressed. The remark has often been made by experienced teachers, that they had probably never taught any particular branch so well, as when learning it themselves; they were then most sensible of the difficulties which the beginner must encounter, and best able to assist him in overcoming them. A scientific professor once said to a lady, in a sarcastic tone—'and so *you* are going to attempt to teach Chemistry.' 'Yes,' said she, good naturedly, 'as fast as I can learn it myself.' The same professor was, afterwards, engaged to lecture and perform experiments before the lady's class, but her pupils complained that his language was so little adapted to their attainments, that they could neither understand his lectures or experiments, until explained to them in the familiar language of their teacher.

A brilliant course of experiments is often of as little use to the beginner as would have been the sight of an exhibition of fireworks, or the ascension of a balloon. They show, indeed, the skill and knowledge of the experimenter, but rather confuse than assist the ignorant pupil. Thus it is that many a college student graduates, without having profited by the elaborate and elegant lectures with which he may have been favoured, because he was ignorant of the language and first principles of the science. These should have been acquired before. Professors in colleges and universities ought not to be expected to devote their time to teaching the *a b c* of Chemistry; those can do this as well, who have not made the attainments they have done, and who are not therefore as capable of being useful in the higher walks of science. We trust no learned Professor will be provoked to say to us, in the spirit of the gentleman just quoted—'and so *you* have attempted to write a book on Chemistry;' for we humbly acknowl-

edge that all we have aspired to, is to prepare those who may be privileged to attend upon his instructions to understand them, without subjecting him to the necessity of explaining first principles.

There is another class, too, and that probably the most numerous, whom we have had in view in the preparation of this work; it is those pupils who may not have future opportunities to pursue the study, except as they are led to make researches by private reading and observation. To give such a taste for chemical pursuits, (without expecting in this little volume to make them chemists,) has been the writer's aim; and especially has she wished to manifest to the young, that every step in the science throws new light upon the economy of nature, and the wisdom of its great Author.

The engravings in this book are in some cases from original designs, but are mostly copied from the works of Hare and Silliman, with the consent of these gentlemen. Besides the important aid of these works, the author has availed herself of assistance from Webster's Chemistry, and has derived valuable hints from Eaton's Chemical Instructor. To Professor Hare she feels greatly obliged for his polite and encouraging attentions in forwarding to her some recent publications of his own, containing drawings of newly invented and highly useful apparatus.

Mont Cervus, Guilford, Vt. July, 1834.

TO TEACHERS.

It is desirable that teachers should be able to make some experiments, let them be ever so simple; but some who use this book, will probably be so situated as to render it very difficult. They must hear lessons in the bustle of the school room; and have neither space nor time for experiments. In view of this, I have endeavoured to make the work plain and simple, and to give such drawings as might compensate, as far as possible, for the want of experiments. Where the classes who use this book can hear lectures, the order of the subjects should be varied to suit that of the lecturer. If your pupils are to hear a lecture on affinity, it would be well that they should previously study upon this subject, and afterwards be examined upon the matter of the lecture as well as the book. In the Female Seminary, at Troy, where for several years, I had the charge of the chemical department, the pupils were required to perform experiments, and to give lectures before the class, on given subjects. In our public examinations each one had her subject assigned her, and was assisted with suitable books, that she might read and investigate for herself. The labour of thus directing them to search for principles, facts, and illustrations, was indeed, in some cases, greater than to have written the lecture; but it was often richly rewarded by its beneficial effect on the mind of the pupil.

From a paper before me containing an arrangement of subjects for these lectures of the pupils in 1829, the following is extracted as an example of the method:

Subjects.

Miss	"	"	Applications of Chemistry to domestic enconomy.
Miss	"	"	Applications of Chemistry to medicine.
Miss	"	"	Supporters of combustion.
Miss	"	"	Combustible substances.
Miss	"	"	Oxygen.
Miss	"	"	Charcoal.
Miss	"	"	Chemical principles involved in the making of bread.

Should this little volume lighten in some degree the arduous task of teachers, and assist them in imparting to their pupils a desire for knowledge, the author will feel that she has not laboured in vain.

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CHAPTER I.

INTRODUCTION.

Of the Nature and Importance of Chemistry.

To you, who are now commencing the study of Chemistry, it may be proper to give some reasons why this is deemed a Science worthy of your attention:—the object of this introductory chapter will be, to explain what Chemistry is, and why it should be studied by young persons.

The knowledge of any science is desirable, because knowledge is in itself good, and it tends to make mankind better, as well as happier.

The time has been, that knowledge was confined to a very few, who were regarded by the ignorant world around them with superstitious dread, and who ruled over the minds of their fellow beings with the most despotic sway: indeed it was thought that men must be kept in ignorance in order that they might be governed.

It is now found to be the case, that the most enlightened people are the most willing to submit to such laws as are necessary for the public good; so in every school, we find the best and wisest pupils most willing to submit to the rules. Since, therefore, knowledge

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What is the object of the introductory chapter?
Why is knowledge desirable?
Has knowledge always been made common?
Why is it our duty to learn?

makes us better members of a community and happier in ourselves, it seems our duty to learn. We live too in a world that God has made, and as his children, we should desire a knowledge of his works.

If you should go into a work shop containing many curious things, you would be likely to ask, what those things *were made of*, and *how they were put together.*

Wherever you look around, *you behold God's workmanship;* and should you not like to know, *what the objects in nature are made of, and how they are put together?* This knowledge is called Chemistry.

But, perhaps, you will be ready to ask, 'since Zoology tells us about animals, Botany about plants, and Mineralogy about minerals, what is there left in nature for Chemistry to explain?'

These sciences, indeed, teach you how to class animals, vegetables and minerals, according to their *outward* appearances, but Chemistry shows you *what they are made of, and how they are put together.*

Here is a piece of *salt*, (I mean of that kind which is used with our food, for there are many other kinds of salt, as Chemistry will teach you;) this being a mineral substance, it is of course classed among such by the mineralogist; perhaps by the shape of its crystals, or some other *external* circumstance.

The chemist examines salt by a method which he calls *analysis*, and he finds that it is made or con-

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What inquiries should you be likely to make if you were to go into a workshop?

What knowledge is called Chemistry?

How does Chemistry differ from Zoology, Botany, and Mineralogy?

By what circumstances would a mineralogist class salt?

Why would a chemist call salt muriate of soda?

sists of an *acid*, called *muriatic*, and an *alkali*, called *soda*, and therefore he calls salt *muriate of soda*.*

By another method called *synthesis*, the chemist proves his analysis to have been correct; that is, he puts muriatic acid and soda together, and finds that the result of this union is common salt.

Here is a piece of *chalk;* the chemist is able, by means of his analysis, to obtain from this a kind of air, called *carbonic acid gas*, and a solid substance called *lime;* thus he calls chalk *carbonate of lime*. By synthesis or bringing lime water into contact with carbonic acid gas, a solid substance is gradually formed, by the union of the lime and gas, and this substance is *carbonate of lime*, or chalk.

Having endeavoured to explain, in a familiar manner, what Chemistry is, we will now give you a more concise definition of it;—'Chemistry teaches us to examine the *elements* of substances, and their laws of *combination*.'

The beginner in this study must not expect at once to understand all the terms which will be used; for instance '*the elements of substances*' cannot be comprehended by one ignorant of the science, and '*their laws of combination*' will appear still less intelligible.

* We are upon the threshold of the science met by a difficulty; since common salt is of late generally considered as a *chloride of sodium*, in the strictest language of the science. But it will be understood that we are attempting to divest it of technicalities as much as possible, and we must therefore use such terms as are most generally received, without attempting to reconcile opposing theories.

How can the chemist prove the truth of his analysis?

By what two methods does the chemist prove that chalk is a cabonate of lime?

Give a concise definition of Chemistry.

Is the beginner expected to understand all the terms which may be used in explanation?

But patient application to study will in time be rewarded by a gradual enlightening of the mind, so that many things which at first may appear dark will seem as clear and simple as the most familiar operations.

We have remarked how Chemistry differs from Natural History, as the three sciences, Zoology, Botany and Mineralogy are called, we will now consider how it differs from Natural Philosophy. The latter science treats of the action of *large bodies* upon each other, as the attraction of the earth and the planetary bodies; it shows what are the *laws of motion*, and the *principles which regulate and govern mechanical operations;* while Chemistry, entering *within* the various substances formed by art or existing in nature, shows us their *internal structure and composition.*

Natural History, Natural Philosophy and Chemistry are all necessary in order to give a complete view of objects; the first explains their *outward appearance;* the second their *mechanical properties;* and the third their *constitution.*

There is no science so intimately connected with the very life of man as Chemistry. Almost all kinds of cooking depend on chemical principles; as also the preparation of medicine, the detection of poisons, the arts of bleaching, and pottery, of making glass, ink, and leather, of dyeing, burning lime, working metals, &c. The invention of the steam engine is owing to an application of chemical principles.

A science connected with so many kinds of business cannot but be highly interesting to all, especially the

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What will be the effect of patient application to study?

How does Chemistry differ from Natural Philosophy?

What are the different provinces of Natural History, Natural Philosophy, and Chemistry?

Why is Chemistry a useful science, and what are some of the arts which depend upon its principles and discoveries?

Why is a knowledge of this science important to all, and especially to be recommended to the young?

young, who know not what their future condition in life may be, or what occasion they may have for various kinds of knowledge.

In most of the mechanical arts, and in some of the professions, those who understand Chemistry, have a great advantage over those who do not; and in the cultivation of the earth, this science has also its important uses, since it teaches the farmer how to analyze different kinds of soil, and what is best fitted for particular kinds of crops.

This science bears an important relation to house-keeping in a variety of ways, as in the making of gravies, soups, jellies and preserves, bread, butter and cheese, in the washing of clothes, making soap, and the economy of heat in cooking, and warming rooms;—to females then, some knowledge of Chemistry must be very desirable. They may indeed learn to perform these operations without understanding any thing of their philosophy; but it is natural to the human mind to seek to understand the *causes of things*, and it is by studying into them that improvements are made.

We are not to suppose that the domestic arts have yet arrived to that perfection of which they are capable; for as chemists are not house-keepers, and house-keepers have not been chemists, there has been little opportunity for the study of domestic economy in its relation to Chemistry.

Young ladies who attend to this study should therefore pay strict attention to all those facts in house-keeping which may be explained upon chemical principles, such as the action of yeast upon flour, and

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What relation does Chemistry bear to house-keeping?

Why have the domestic arts not yet received great improvement from Chemistry?

What should young ladies who study Chemistry pay particular attention to?

of pearlash upon sour dough, the change of cider into vinegar, the advantage of keeping a vessel covered in order to hasten the boiling of water, &c; they should, in short, endeavour to make a practical application of their knowledge to the business of life.

It should be considered by every young person that the object in studying Chemistry is not merely to *appear* learned, and make a display by talking about *caloric*, *oxygen*, &c., but in reality to become wiser, and better fitted for usefulness in the world.

There is one view in which the science of Chemistry produces in the mind thoughts of a deep and solemn kind, and calculated to humble the pride of man. When we learn that our own bodies, are composed of a few elements of the same nature as those which form the very worm that crawls, and that at death the union which subsisted between these elements being dissolved, they will be separated and pass into the substance of the weeds that may spring up from their remains; we must feel with him of old, who in his humiliation, exclaimed, 'I have said to corruption, thou art my father and to the worm thou art my mother and my sister.'*

But there is a portion of ourselves which is beyond the scope of chemical science, which cannot be analyzed, because it is incapable of being separated into parts. It is that within us which thinks and feels, which knows good from evil, which is destined to an immortal existence, and which at death passes from its prison of clay to the world of spirits.

*Job XVII, 14.

What should be the object of every young person who studies Chemistry?

In what view of the subject does Chemistry produce solemn reflections?

What portion of ourselves is beyond the scope of chemical science?

All then that is done for the improvement of the mind either in knowledge or virtue, will be permanent, while the labour bestowed upon the care and decoration of the body will perish with that frail and decaying substance.

CHAPTER II.

Different kinds of Attraction. Explanation of Terms. Simple Affinity. Elective Affinity. Double Elective Affinity.

BEFORE proceeding to consider the *substances* which Chemistry examines, we shall investigate the operation of a *power* by which the simple elements of nature are combined and kept together, thus forming all the variety of objects which our earth presents. This power is called *chemical attraction*, or *affinity*.

By the term attraction, in its most extended sense, is meant, *the tendency of bodies to approach each other.*

Gravitation is that kind of attraction which exists between distant bodies; it is this which causes a stone to fall to the earth.

Cohesion is that kind of attraction which holds together similar particles of bodies as in a lump of salt.

Affinity or chemical attraction is that force which unites different substances into one compound substance,

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What reflection concludes this chapter?
Of what power are we now to investigate the operations?
What is meant by attraction in its most extended sense?
What is gravitation?
What is cohesion?
What is affinity?

thus salt is composed of *muriatic acid* and *soda* by chemical affinity.

Besides these modes of attraction are reckoned those of Electricity and Magnetism; although chemical affinity may be occasioned by electricity, and magnetism is thought to be connected with it.

The attraction of gravitation is the power which retains the planets in their orbits. This power is such, that if two bodies of equal size were placed at ever so great a distance from one another, and if there were no other bodies in the universe to attract them in different directions, they would rush towards one another and meet in a point equally distant from the one whence they started. The force of gravitation depends upon the size of a body and its distance; thus the smaller body will overcome the attraction of a larger one at a greater distance. The moon is smaller than the earth; but supposing that body should advance very near to the earth so that a stone thrown upwards would approach much nearer to the moon, the stone instead of falling downwards from the force of the earth's attraction, would fly off to the moon.* A leaden plummet suspended by a line from the top of a mountain is attracted towards its side, the nearness of the mountain overcoming the earth's attraction, which tends to draw it downward.

* Several simple experiments may be made to show the power of attraction, as 1. place two globules of mercury or quicksilver on a piece of dry glass, and push them slowly towards each other, when within a certain distance, they will rush together.

2. If two pieces of cork or wood be placed in a dish of water near the centre, they will approach each other, with a rapidity of motion proportioned to their size.

What other modes of attraction are there?

Give a more particular account of the attraction of gravitation?

The *attraction of cohesion* differs from that of gravitation, because it operates only upon small particles of bodies which are in contact. A piece of marble shows that it is composed of a collection of very small particles; these are held together by cohesion. This attraction may be overcome by mechanical force, as pounding, grinding &c., but the elements of which marble is composed, that is *carbonic acid* and *lime*, can only be separated by means of chemical analysis, or by fire.

Chemical attraction or *affinity* holds together the elements of bodies. It is necessary to understand this subject in order to comprehend many of the changes which can be produced by means of chemical operations. It is introduced in the beginning of your study that you may be prepared to comprehend what will follow.

It is necessary here to make you acquainted with some terms of frequent use in Chemistry. A *simple* or *elementary* substance is one which cannot be separated or decomposed by any chemical process.

These simple substances, or elements, are about fifty in number; as you are yet unacquainted even with the names of many of them, it would be of little use to give them to you to learn; after you shall have become somewhat acquainted with them, we shall wish you to understand how they are classed by chemists.

A *compound body* is one which consists of two or more simple bodies or elements; thus common salt is a compound body, consisting of soda and muriatic acid, which are united by means of chemical affinity.

How does the attraction of cohesion differ from that of gravitation?

Why should Chemical attraction be introduced in the commencement of the study?

What is a simple or elementary substance?

How many simple substances or elements are there?

What is a compound body?

Decompose—this means to separate the elements of compound bodies; thus to break salt into pieces would not be to decompose it, but to separate it mechanically; but in order to decompose salt, the elements must be disengaged from the union in which they are held.

Analysis—this is a very important operation in chemistry, and consists in a separation of the parts of a substance in order to ascertain the elements which compose it. The methods of performing chemical analyses are various, and will be explained as we proceed. Chemical analysis is performed by the decomposition of substances.

Synthesis consists in forming a compound body by putting together two or more substances.

The constituent parts of bodies may be ascertained either by analysis or synthesis; thus water is found by analysis, or a disunion of its elements, to consist of two kinds of gas, and by bringing these two gasses together, water is formed. The correctness of the analysis is here proved by synthesis.

You know the difference between a *solid* and a *liquid*—that is, the attraction of cohesion is less powerful in a liquid than in a solid; you can more easily penetrate water than wood.

A *gas* is a substance in which the particles are still less governed by cohesive attraction; the air, although it exists in the form of a gas, is not generally classed among gases, because it may be condensed by pressure or cold. When you burn sulphur, a yellowish vapour of a disagreeable odour, rises; this is *sulphurous acid*

What is meant by decomposing a substance?
What is analysis?
What is synthesis?
By what two methods may the constituent parts of bodies be ascertained?
What is the difference between a solid and a liquid?
What is a gas?

gas. We shall hereafter consider the various kinds of gases.

There are two more terms which it is important you should understand: *homogeneous* means all of one kind; thus when salt is pounded, all the particles are found to be of the same nature. Cohesive attraction operates chiefly upon particles which are homogeneous. *Heterogeneous* means mixed; chemical affinity can only take place between heterogeneous particles; it is generally the strongest between those substances which are the most unlike.

There are *three* important particulars to be remembered respecting the nature of Chemical Affinity:—*it is exerted at insensible distances; between particles only; and those particles are always heterogeneous.*

SIMPLE AFFINITY.

Simple Affinity is that force which causes the particles of substances to unite, and produces a new compound.

Experiment.—Take a wine glass containing a little water, and pour into it some sweet oil; you will perceive they do not unite, but the oil floats upon the surface. Add a small bit of pearlash and stir the mixture. You now perceive that a union of the three substances is produced, and that a new compound, like soap is formed.

Explanation.—Between water and oil there is no affinity, and therefore they remain without uniting;

Define the terms homogeneous and heterogenous.

What are three important particulars respecting the nature of Chemical Affinity?

What is Simple Affinity?

What experiment illustrates Simple Affinity?

Give an explanation of the experiment.

pearlash having an affinity for both, serves as a bond of union between them.

Pearlash contains a large portion of potash, which belongs to a class of substances for which oil and fat of all kinds have a strong affinity. These substances are called by the general name of *alkalies;* they include lime, soda, potash, &c. We shall consider their nature as we advance in our study; at present it may be sufficient to observe that they have a peculiar acrid taste, as you may have perceived in the ley made from ashes; that they change vegetable blue to a green colour, and have a strong affinity for *acids*, a class of substances possessing very different properties from alkalies.

Acids are of various kinds, and will be explained hereafter. You know what is meant by an acid taste like that of vinegar, of a lemon, &c.; but there are many properties of acids which, without a knowledge of Chemistry, you would not become acquainted with.

We have shown you, by the experiment with water, oil, and pearlash, an instance of simple affinity. The making of soap is conducted on exactly the same principles as is here illustrated.

Every economical family save all the bits of fat which are unfit for cooking in order to use for making soap. The ashes which are collected daily from the fire places and stoves are saved for the same purpose. When the soap is to be made, the ashes are put into a large cask called a *leach* and wet with water until they are *saturated*, that is, until they have taken up as much water as they will contain; after this, water being added gradually, the *ley* runs off from holes near the bottom of the leach. This ley

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What is said of alkalies?
What is said of acids?
By what chemical operation does the making of soap depend?
Describe the process of making soap as practiced in families?

contains the strength of the ashes, which besides some other substances abound in potash; it is therefore highly *alkaline.* The materials which have been collected for the purpose, usually called soap-grease, are then thrown into a large iron kettle with the ley where they are boiled together.* A chemical union takes place between the alkali and the grease, and soap is the new compound which results from this combination.

By throwing the grease into cold ley, soap will gradually be formed. This is called by house-keepers *cold* soap; but heat causes the action of affinity to be more rapid, and for this reason most chemical operations are performed by the aid of heat.

Hard soap is made with soda instead of potash. The finer kinds of hard soap are made of olive or sweet oil, water, and soda.

The volatile liniment so useful for burns and sore-throats, is made of ammonia, (hartshorn,) sweet oil, and water.

ELECTIVE AFFINITY.

The force of affinity is different between different bodies.

Elective affinity signifies that preference which one substance has for another, by which a third substance is excluded.

* In cities, and large villages it is generally thought more economical to dispose of the ashes and grease to the soap manufacturer and receive soap in return. In the country, it is necessary for every family to make their own soap.

How is cold soap made?
How is hard soap made?
How is volatile liniment made?
Is the force of affinity equal between all bodies?
What does elective affinity signify?

Experiment.—Pour a few spoonfuls of camphor which has been previously dissolved in spirits, into a tumbler, add a small portion of water, and the camphor will collect in little scales. It is then said to be *precipitated.*

Eplanation.—The camphor and spirits were united by the force of *simple affinity*, and formed a clear solution ; on adding the water, the spirits having a stronger affinity for that, than for the camphor, united with it and excluded the camphor which again appears as a white and solid substance.

In the next experiment, we shall speak of *sulphuric acid* ;* as it is a substance of great importance in many chemical operations, it may be well to tell you that its common name is *oil of vitriol*, and that it is made by the union of *sulphur* with a gas called *oxygen*, with which you will soon be made acquainted. The union of sulphur and oxygen is an instance of *simple affinity.*

We shall also in our next experiment speak of *muriatic acid gas.* This will be a *new term*, but it is impossible, let us begin where we will in Chemistry, not to be obliged to introduce terms that

* Those pupils who are provided with a Dictionary of Chemistry will do well to refer to it when any new substance is named. It is impossible to explain every *term*, while we attempt to proceed systematically in the developement of the science, as this must be continually taking us from the main path. The use of a Dictionary of terms renders such irregularity unnecessary. No systematic work can be sufficiently full in explanation to preclude the importance of having at hand a Dictionary.

By what experiment with camphor and water is elective affinity shown ?

How is it explained ?

What is said of sulphuric acid ?

What is said respecting the use of new terms before their explanations ?

cannot at first be familiar to the beginner. We shall now propose to you another method of illustrating *elective affinity.*

Put into a wine glass a teaspoon full of fine salt, and pour upon it the same quantity of sulphuric acid. You will see a white vapour rise from the mixture, and will perceive that the substance in the wine glass is of a different nature from either of those which were used for the experiment.

Explanation.—Common salt is a compound substance consisting of *soda* and *muriatic acid.* The soda having a greater affinity for the new acid which is added, *elects* it, and excludes the muriatic acid, which escapes in the form of a *gas.* This occasioned the vapour which appeared to rise from the glass. But the muriatic acid gas would be invisible, except that it has a strong affinity for water, of which there is always more or less in the air; uniting to particles of water it forms a little cloud.

The substance which remains in the glass is the *soda* united to its *new friend* the *sulphuric acid;* this is called *sulphate of soda,* it is the same substance which is so common in medicine under the name of *Glauber's*

What experiment may be made with salt and sulphuric acid?
Explain this experiment.
What is the substance remaining in the glass?

Salts, so called from the person who first added it to the list of medicinal articles.

Experiment.—Into a solution of liquid *muriate of lime* let fall a few drops of *sulphuric acid.* The muriate of lime will be decomposed, a sulphate of lime will be formed, and the muriatic acid will be set free, and pass off in the state of a gas.

Explanation.—The lime has a greater affinity for sulphuric acid than for muriatic, it therefore *elects* the former, and the latter is excluded.

It is by means of *elective* affinity, that the chemist is able to decompose substances which otherwise could never be separated. For you perceive that chemical decomposition is quite different from mechanical separation. By no other means than elective affinity, could the muriatic acid and soda which compose salt, be separated; for let the salt be pounded or ground into the smallest possible particles, every particle would consist of muriatic acid and soda.

DOUBLE ELECTIVE AFFINITY.

There is still another form of affinity, more wonderful in its effects than those we have already considered. This is called *double elective affinity, for by its means two compounds, each consisting of two ingredients, are decomposed, forming two new compounds.*

In many cases one *single compound* consisting of two ingredients cannot be decomposed by any *single element*, as *sulphate of soda* cannot be decomposed by *lime*, because sulphuric acid attracts soda more strongly than it does lime.

What experiment may be performed with muriate of lime and sulphuric acid?

Why does the lime unite with sulphuric acid?

Could the elements which compose salt be separated in any other way than by elective affinity?

What is double elective affinity?

Can the sulphate of soda be decomposed by lime?

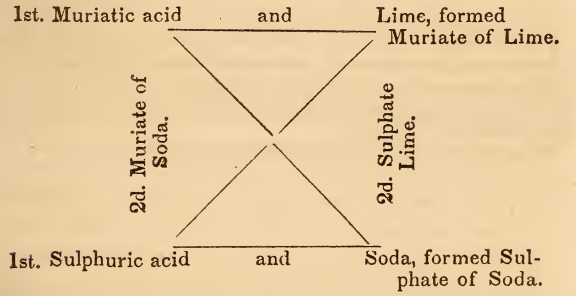
Neither can the sulphate of soda be decomposed by *muriatic acid*, because the sulphuric acid attracts soda more strongly than the muriatic acid does.

But though neither lime, or muriatic acid singly can decompose the sulphate of soda, the *muriate* of lime which is a compound of both, will effect this.

Experiment.—Take muriate of lime and of the sulphate of soda, and dissolve them in separate tumblers, then mix them and a solid substance, the *sulphate of lime*, will settle at the bottom of the glass, while a solution of the muriate of soda will be above it.

Explanation.—Although neither muriatic acid or lime singly could separate the two substances which compose the sulphate of soda, yet by their mutual action at the same instant they cause the suphuric acid to unite itself to the lime, and the soda to the muriatic acid; thus there is a mutual exchange of partners. Lime is attracted strongly by *sulphuric acid*, soda is attracted by *muriatic acid*, and thus as if by general consent the old connexions are broken up and new ones formed.

The following figure may show the process more fully; the horizontal lines show the substances before mixture, and the diagonal lines after mixture.



What will decompose the sulphate of soda ?
Describe the experiment which proves this ?
Explain this experiment ?

It may be difficult for the beginner to understand this complicated process; should it perplex you it will be best to pass on to what you will the more easily comprehend; and then when you take up this subject again it will seem more intelligible.

We have in this chapter considered the nature of attraction in general, its different kinds, and especially the different kinds of chemical attraction or affinity; these were *simple*, *elective*, and *double elective*.

'There are few compound substances in which the chemist has not been able to overcome the resistance of affinity. The means of doing this are various and often very complicated; many forces may be made to act upon a substance which seldom effectually resists when the decomposing forces are judiciously employed.

'*All the processes which may be resorted to in the treatment of different substances can only be known by a knowledge of the action which bodies exercise upon each other, of the changes which accompany this action, and of the compounds which result from it; it is this knowledge which constitutes Chemistry.*'*

* Dictionary of Chemistry.

Can it be decomposed by muriatic acid?

How does the figure show the process of double decomposition?

Is this subject easy to be understood by the beginner?

What have we in this chapter considered?

Are there many compound substances which the chemist has been unable to decompose?

What knowledge is said to constitute Chemistry?

CHAPTER III.

Chemical Affinity. Definite Proportions. Laws of Affinity.

As the subject of chemical affinity is one which the student should well understand, we will devote a little more time to the consideration of some of its phenomena.

By *phenomena* you are to understand *changes* and *appearances*. Because it seems a hard word, you may suppose it difficult to be understood, but it is a convenient term to express an idea which otherwise would require several words. By the *phenomena* of chemical affinity, we mean those *changes* which it produces on bodies, and the *appearances* which accompany these changes.

We have seen by the experiments in the foregoing chapter, that the change produced by chemical affinity is very great; so much so, that it seems in many cases wholly to alter the nature of substances.

Sulphuric acid and *potash* in a separate state are distinguished by qualities essentially different: potash is a solid alkali which on being added to blue vegetable infusions changes their colour green. Sulphuric acid is a liquid which changes blue vegetable colours red. The two substances are also distinguished by their peculiarities of taste, and their different action on other bodies.

But let us add sulphuric acid to potash, in small quantities at a time, we shall at length attain a certain

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What is meant by the expression the phenomena of chemical affinity?

What is said of the change often produced by chemical affinity?

What is said of sulphuric acid and potash in a separate state?

What change takes place by putting them together?

point, at which the compound will exhibit neither acid or alkaline properties, having a bitter taste, and producing no effect on blue vegetable colours.

In the case of the chemical union between sulphuric acid and potash, we see two of the most powerful and corrosive substances with which we are acquainted, producing a third which may be handled or swallowed without danger. This third substance is *sulphate of potash*, ranked in Chemistry among the *salts*, an important class of substances formed by the union of acids and alkalies.

When opposing properties are thus destroyed by chemical combination, the two substances are said to *saturate* each other, and the exact point at which this change is accomplished is called *saturation.*

Experiment.—Put into two wine glasses half a tea spoon of *muriatic acid* to each—weigh in delicate scales two equal parts of *carbonate of soda*, about a teaspoon full to each glass; put gradually small quantities of these parcels into the two glasses of acid; at first there will be a violent action accompanied by a hissing noise, this is called *effervescence*, and it will cease when the acid is saturated, or has taken up all the alkali with which it will unite. On weighing what remains of the carbonate of soda, you will find the two portions equal, that is if you have been careful to stop putting it in to the glass at the exact point when the effervesence ceased in each. On examining the contents of the wine glasses you will find them to be a solution of common salt.

Explanation.—Carbonate of soda is composed of carbonic acid and soda—but soda has a stronger affin-

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What is sulphate of potash?

What is meant by saturation?

Describe the experiment with muriatic acid and the carbonate of soda?

Explain the changes which take place in this experiment.

ity for muriatic acid than for carbonic, it therefore unites with the former and expels the latter, forming the *muriate of soda* (common salt.) The effervescence was caused by the escape of the carbonic acid gas.

But what we are chiefly to illustrate by this experiment is the law of *definite proportions*, viz. that when two substances have united up to a certain point which nature has fixed, there can no longer be any combination between them. Should you continue to drop into the acid, pieces of the carbonate of soda after it had received its definite proportion, there would be no union, but the carbonate of soda would fall to the bottom of the glass and remain unchanged in its nature.

Water will unite with common salt until it becomes incapable of dissolving more. In making brine for salting meat, (especially pork which requires a strong brine in order to preserve it as long as that article is usually kept in families) it is best always to have a quantity of salt at the bottom of the barrel, which will always be the case when more is put into the water than that can contain. No brine can be stronger than that in which the water is saturated with salt, but the salt remaining at the bottom is a proof that this is the case.

In the instance of brine, the common salt or muriate of soda does not (as in the last experiment was the case with the carbonate of soda,) change its nature by parting with one of its elements, but unites with water, without suffering any decomposition. But in the one case there is a great change of properties, and in-

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What is this experiment chiefly intended to illustrate ?

Is there a point beyond which water will not unite with common salt ?

Does common salt or muriate of soda change its nature by its union with water, as the carbonate of soda does in the experiment ?

deed the formation of an entirely new substance, while in the other, the qualities which belonged to the original substances remain in part the same; that is, the taste and other properties of brine are like that of salt.

In the case of the carbonate of soda and muriatic acid, a violent action was occasioned by the new combination, but in the union of common salt with water, as nothing is excluded, the operation goes on in a quiet manner unattended by any remarkable phenomena.

By affinity some substances unite in *indefinite proportions*, while their properties are not essentially altered.

If you mix sulphuric acid and water, or alcohol and water, their properties will remain the same, although the particles being diffused among the water there will be less in a given space.

We will now consider some of the most important laws* of chemical affinity, as from the explanations already given you will probably be able to understand them.

1. *Affinity takes place only between bodies of a different nature*, as between an acid and an alkali, the attraction between particles of a similar nature being that of cohesion, or, as it is sometimes called, of *aggregation.*

2. *Affinity takes place only between the most minute particles of bodies;* therefore the more minutely substances are divided by pounding, grinding, or by solution, the more readily they act upon each other; thus

*The complicated nature of chemical equivalents is not here discussed as it might perplex the beginner at the commencement of his course.

Are the phenomena in both cases the same?
Do some substances unite in indefinite proportion?
What examples of this can you give?
What is the first law of chemical affinity?
What is the second law of chemical affinity.

if a lump of sulphur is thrown into alcohol no action will take place, but if sulphur be finely divided the bodies unite and form a transparent solution.

3. *The union produced by affinity is permanent and cannot be destroyed by mechanical means;* solutions of salt and sugar are not decomposed by standing for any length of time, but a mixture of powdered chalk or coal having no affinity, would in time exhibit a separation, the solid part settling at the bottom and the water appearing clear.

4. *Bodies having no affinity are sometimes brought to unite by a third body;* thus an alkali unites oil and water.

5. *The force of affinity is different between different bodies;* this was illustrated in the decomposition of common salt by sulphuric acid; where the affinity for soda was found to be greater for sulphuric than for muriatic acid.

6. *A change of temperature often takes place at the moment of combination;* this is very apparent in the case of adding sulphuric acid to water, when the heat becomes so great that it is impossible to hold the glass containing the mixture in the hand.

We shall not dwell longer upon the subject of chemical attraction, although as we proceed we shall have frequent occasion to refer to it for the explanation of many chemical changes. Cohesive attraction, the attraction of Gravitation, of Magnetism, and Electricity, are subjects which belong more especially to the department of Natural Philosophy, though as Electricity is supposed to have an important influence on chemical phenomena, we shall hereafter pay some attention to it.

What is the third law of chemical affinity?
What is the fourth law of chemical affinity?
What is the fifth law of chemical affinity?
What is the sixth law of chemical affinity?
What kinds of attraction belong to the department of natural philosophy?

CHAPTER IV.

Matter. Light—its Effects—its laws of Motion. Rays of Light. Colour.

We are now prepared to commence an examination of *matter*, since we have considered that great law which chemically unites or brings together the *elements* out of which are formed the various natural and artificial substances which exist upon the earth.

What is matter? It is something which possesses qualities that are in some way manifested to our senses. Your book is matter, so is your table, the trees and stones, the bodies of animals and your own body; all these are *solid* matter. The water and all kinds of *liquids* are another kind of matter.

Is the *air* matter? When you look from the place you now sit, across the room, you see some space which *seems* to be empty, but it is not so in reality, it is filled with air; move your hand rapidly, and you will feel the air; its motion will be attended with a sensation of coolness. What you can discern by any one of your senses is matter. Feeling or *touch* is a sense; air is perceived by it, therefore air is matter. It is a *gas*.

Matter exists in three forms, that of a solid, a liquid and a gas.

There are substances which chemists consider to be matter that appear under a form different in many re-

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What preparation have we made towards commencing at examination of matter?

Give some account of matter?

How do you know that air is matter?

Under how many forms does matter exist?

Are there substances which do not come under any of these classes, that are considered to be matter, and how are they manifested to us?

spects from our ideas of material substances ; these are *light* and *heat*, *electricity* and *magnetism;* they are manifested to us only as they act upon other substances.

Light is not what we see, but it is that, which, by falling upon other substances, and then coming to us, seems to tell us of their existence. If you enter a room in the dark you do not perceive what furniture it contains, but enter the same apartment in the light of day, and your eyes at once inform your mind of the existence of chairs, tables, carpets, &c.

The picture made upon the eye is the effect of light. Its touch is very gentle, so much so that unless the light is very strong, it gives no pain to that delicate organ the eye ; but unless it touch the eye, how can it form an image there of the furniture of a room, of the landscape abroad and the expanse of the heavens ?

Light is a most wonderful agent, and the organ on which it produces its effect is no less wonderful. When you look upon the heavens in a clear star-light and behold its countless millions of suns and worlds, separated as they are from each other by distances beyond the power of numbers to compute, you see all this in a picture not more than an inch in diameter. Your eye does not go to the stars to learn their places and arrangement, but light travelling in every direction comes to your eyes and imprints there, that which your minds contemplates. So that it is not the heavens which you actually see, but a picture of them upon that part of the eye called the *retina.*

Do we see light, or is it merely an agent to reveal other substances to us ?

What produces the picture upon the eye when images are there formed of external objects ?

When we look abroad, do we see objects themselves, or pictures of them ?

The study of the phenomena of light, as it is connected with sight or vision belongs to Natural Philosophy, and is called *optics.*

Light, however, as one of the substances in nature, and as causing some chemical changes claims the notice of the student in Chemistry.

Although light is classed among *material* substances, it cannot be weighed, because neither our balances or organs of sense are sufficiently delicate. It is therefore called *imponderable.**

Light proceeds *directly* from the sun and the fixed stars, and from the moon and the planets by *reflection ;* this is called *celestial* light; it also accompanies heat in fire and in other cases of chemical combination, and this is called *terrestrial light.* We say other cases of combination because fire itself, or the combustion which produces it, is supposed to be caused by chemical affinity.†

Light moves with astonishing *velocity ;* it is computed that it travels at the rate of *two hundred thousand miles in a second.* A ray of light is supposed to pass from the sun to the earth in about *seven minutes.*

Light moves in *right lines,* never in curves; when turned at all out of its course, it is always at an angle.

* The word *pondus* in Latin signifies weight, from whence comes *ponderable* having weight and *imponderable* having no weight.

† Combustion, by some of the most distinguished chemists of the present day is supposed to depend on the union of opposite electricities, the oxygen of the air furnishing the negative and the combustible substance the positive electricity.

What is the study of the phenomena of light as connected with seeing, called?

Why is light considered is connected with Chemistry?

Why is it called *imponderable?*

What are the sources of light, and what are its different kinds called?

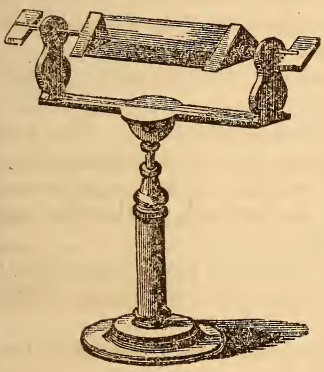
What is said of the velocity of the motion of light?

In what lines does light move?

When light falls upon polished surfaces it is thrown back, or *reflected.* A person standing directly before a mirror sees his image as if it were fronting him, but if he stand a little on one side, his image will appear just as far upon the other.

The rays falling from the person upon the mirror are called *incident rays,* those which are thrown back are called *reflected rays ;* the angles which they make are always equal. Thus two persons at opposite angles of a plane or flat mirror, see each other's images, although they cannot see their own.

Nothing can appear less like a compound substance than a ray of light, and yet it is found to consist of seven colors, which are separated by means of a prism.



A prism is a triangular piece of glass sometimes, as in the figure, supported on a frame for more convenient use, though the glass simply may answer all necessary purposes.

The prism should be used by placing it before a hole in a window shutter, the room being dark except by means of the light received through the aperture

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What effect is produced when light falls upon polished surfaces ?

What are *incident* and what *reflected* rays ?

Is light a compound substance ?

What is a prism ?

What effect has the prism upon light as it passes through it ?

in the shutter ;—the light in its passage through the prism is separated into red, orange, green, blue, indigo, and violet.

The red ray is the least *refrangible* that is, it is the least turned out of its course, and the violet is the most refrangible ; these different rays will be seen arranged in the order in which they have been named upon any substance placed in a proper direction before the prism.

The red ray is found to possess the most and the violet ray the least heat of the seven primary colors.

You may see in a rain-bow exactly the same effect produced by the separation of the rays of light as that exhibited by the prism. The drops of water or falling rain, through which the sun's rays pass, act as the prism to break and reflect them according to their different degrees of refrangibility.

By mixing the seven primary colours in due proportions, white is produced.

Colours are not in bodies themselves. The rose which you call red, is so made as to absorb all the other rays and reflect the red ray. The leaves absorb all except the green ray. In the dark, neither the rose or its leaves has any colour.

White bodies reflect all the rays, black ones absorb all and therefore reflect none; for this reason, white and black are not considered colours.

It will at first appear to you a very strange idea that the colour of different substances is not in them-

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Which ray is the most refrangible, and which the least so ?

Do all the rays possess an equal degree of heat ?

What produces the various colours of the rain-bow ?

What is the effect of mixing the seven primary colours ?

Do colours belong to bodies, and and if not, how are they produced ?

Why are white and black not considered as colours ?

Is that colour which an object seems to have, the one for which its particles have an affinity ?

selves but is caused by the manner in which they reflect light to our eyes. We cannot explain why some bodies appear red, others green, &c. except by saying that it is because their particles have an affinity for the other rays of light, and reflects the red or green or whatever colour they may appear to us to have. For you must understand that the colour which an object appears to have, is, in reality, that which it *has not*, or that which it rejects or throws off.

It follows from what has been said, that colour depends on the capacity which the particles of bodies possess of absorbing or reflecting the different rays of light.

Experiment.—Soak in water some leaves of purple cabbage, the roots of radishes, or flowers of blue violets, you then obtain a vegetable blue colour. Pour into this a few drops of sulphuric acid and the colour is changed to red.

Explanation.—Since sulphuric acid is a colourless liquid, it cannot be that mixing it with the blue liquid, should change its colour in the same way that by putting red and yellow paint together you produce orange, an intermediate colour, which partakes of the nature of both. We infer then, that by the union of the blue infusion with the sulphuric acid, a new arrangement of the particles took place, which caused a different coloured ray of light, viz, the red to be reflected.

Thus by mixing solutions of corrosive sublimate and pearlash, both colourless substances, we are presented with an orange colour. By mixing a solution of pearlash with blue vegetable colours we have green. An infusion of nut galls mixed with one of copperas

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From what does it appear that colour depends on ?

What effect according to the experiment does sulphuric acid have upon a vegetable blue colour ?

How is this experiment explained ?

Give some other examples of the changes which are produced upon colours by the mixing of different stubstances ?

produces black; by pouring in a small proportion of sulphuric acid, the black changes to white; that is from a state in which the particles reflected all the rays of light, they are thrown into one in which they absorb all and reflect none.

These are effects produced by chemical combinations. You can perceive then how important it is to those who mix colours either for dyeing or painting, to understand as far as possible, what may be done with different substances in the way of producing variety and beauty of colours by means of such combinations.

Light is contained in all bodies, though in many cases it remains in a state invisible to us. You have seen sparks of fire produced by two pieces of iron or other hard bodies being brought forcibly and suddenly in contact; the fire was made manifest by means of the light which accompanied it.

Light and heat are not always connected; the light of the moon called *lunar** light is unaccompanied by heat.

Some animals emit light, as the glow worm and several species of fire-fly. Those who sail upon salt water often observe a luminous path seeming to follow the vessel, this is owing to animal matter dissolved in sea water, or to collections of living animals so small and unformed as to exhibit no other appearance than a jelly like mass. Putrid fish, rotten wood and many other substances emit light. Phosphorus derives its name from this property.

The importance of light to the growth of vegetables

* From luna, the Moon.

What is important for those who mix colours for dyeing or painting?

Does light exist in any bodies in an invisible state?

Are light and heat always connected?

What is said of animal and other substances which emit light?

is well known—if they grow at all in the dark, they usually exhibit a sickly appearance, and are destitute of colour and fragrance.

Both plants and animals exposed to a strong light usually exhibit richer and more lively colours than those which live deprived of light, or where it is feeble; thus, the birds, insects and flowers of the torrid zone surpass those of the other parts of the world, in the brilliancy and beauty of their colour. In the torrid zone only, are black people found, except it be among their descendants who have been carried to other parts of the globe.

CHAPTER V.

Heat or Caloric.

We could not explain to one who had never felt the *sensation of heat* what it is, any more than we could make a blind person understand the nature of colours, or a deaf one the nature of sounds.

This is the case with all our *sensations;* that of taste for example can be explained only by reference to the sensation itself; there are various kinds of sweets, as that of honey, of sugar, and of many fruits which all differ from each other in a manner which could never be explained to one who had not tasted them.

Do plants grow without light?

Why are the animals and vegetables of the torrid zone, of a richer and deeper colour than in other portions of the earth?

Could we explain the sensation of heat to one who had never experienced it?

Is this the case with all our sensations?

But the *sensation* or feeling of heat is as different from the *cause* of heat, as the sensation we call sweet is from the sugar which produces it.

The *feeling* of *heat* is caused by a substance called *caloric*, from the Latin *calor*, heat.

Caloric like light is an imponderable body, or one that has no known weight.

Caloric and light are intimately connected; the one being generally acompanied by the other. But they are proved to be two distinct substances; and as we have shown that light sometimes appears without caloric, we shall also find that caloric may be perceived when there is no evidence of light.

Iron may be made so hot that you cannot bear your hand upon it, and yet it will exhibit no light. Here is an instance of caloric without light.

Caloric and light may be distinguished by the different sensations they produce. Light is only perceived by the eyes, it produces *vision* or *sight*. Caloric may be perceived by its effects on every part of our body, which is one general organ of *touch*: the sensasation it produces is that of *heat*.

Caloric exists in two different states *free* and *combined*.

Free caloric comprehends all the sources of heat which are manifest to our senses as that which comes from the sun, from the fire and from heated bodies.

Combined caloric exists in a concealed state in all

Does the feeling of heat resemble its cause?
What causes the feeling of heat?
Is caloric known to have weight?
Are caloric and light the same substance?
Give an example of caloric existing without light.
How may caloric and light be distinguished?
In what different states does caloric exist?
What is meant by free caloric?
How does combined caloric exist?

bodies. It is called latent or hidden caloric, and in this form exists even in ice itself.

You will doubtless find it somewhat difficult to believe that to be a real existence which has never been seen; but yet that something which causes heat, which produces flame, and which is active in the vegetable and animal creation has never been seen by us; its *effects* are around us on every side, but it is itself invisible.

Light and caloric seem to be in many respects the representatives and types of Him who created them and since we cannot deny that there is something which, though itself unseen, produces vision and reveals to us the forms of bodies; that there is something which produces the sensation of heat which is also invisible, can we but acknowledge that there may be, around and about us, one great and pervading Spirit, the source, of mind, the Creator of matter and the director of all things visible or invisible?

When we speak of caloric, you will, therefore, understand that we mean a something which actually exists, and not a mere property or quality of matter;—divisibility is a property of matter denoting that it is capable of being divided; but divisibility is not itself a substance, any more than high or low, hard or soft are substances.

Caloric passes from one substance to another; *it is only when in motion* that we perceive its existence. When it is entering our bodies, we feel warm or hot: when it is leaving them we feel cool or cold according to the degree of caloric we receive or lose.

All our sense are affected by *motion.*

Do we perceive caloric itself, or only its effects?

How do light and caloric represent their creator?

Do you consider caloric as an actual existence, or a mere property of matter?

When is it that we perceive the existence of caloric?

The motion of light produces	vision.
That of air	hearing.
That of odoriferous particles	smelling.
That of sapid substances	tasting.
That of bodies which touch us	feeling.

Since there is a something which produces heat, it would be natural to suppose that when this enters bodes it would increase their size; this is found to be the case; from whence this principle is established, that *Caloric expands all bodies.*

Caloric expands *solids.*

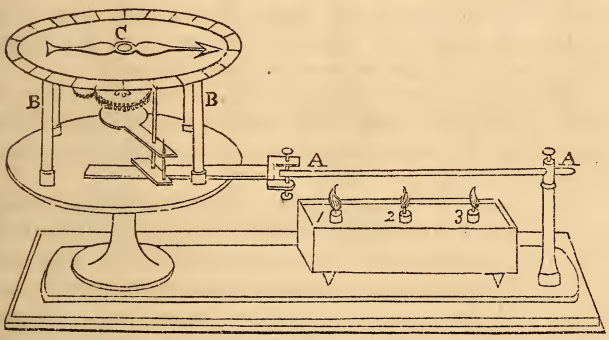
Experiment.—Take an iron rod *a* fitted in length to the space, *b*, and in diameter to pass through the circular aperture at *c*; heat the rod to redness and it will be found too long to fill the one space, and too thick for the other. On cooling, the rod will again in length, and diameter, fill the same spaces as at first.

Explanation.—The caloric which enters into the iron, crowds itself between the particles of metal and separates them at a little distance; thus increasing the size of the rod.

How are all our senses affected by motion?
Does caloric enlarge the size of bodies?
By what experiment is the expansion of solids illustrated?
How is this explained?

On putting the heated rod into cold water, the caloric leaves it and passes into the colder substances and the rod is of the same dimensions as at first. It would cool in the common air, but not so soon as in cold water.

An instrument called a *pyrometer* from the Greek *pur*, fire, and *metron*, measure, has been invented to show the degrees of expansibility of different metals by heat. The figure shows a rod of metal, A A, resting horizontally upon supporters.



One end of the rod touches the wheel work B, B, which is so connected with the index C, that a slight motion of the former, causes a considerable movement in the latter. The rod of metal, being heated by the lamps 1, 2, 3, presses against the wheel work which communicates motion to the index. The expansibility of the metal is denoted by the degrees marked on the plate.

When the rod is again cooled, is its size affected ?
What is a pyrometer ?

The pendulum of a clock is longer in warm than in cold weather; the vibration of the pendulum is quicker or slower in proportion to its length, or the longer the pendulum is, the slower the clock will go; thus in very cold weather, clocks are liable to go too fast, on account of the contraction of the pendulums.

A piano or harp that has been tuned in a cold room will often appear out of tune when the room is warmed; this is because the strings are expanded by heat.

Glass stoppers sometimes get fitted into the necks of decanters so that it is difficult to take them out; if the bottle is plunged into hot water up to the neck, or a sponge containing hot water is applied to it the glass will expand and the stopper become loosened.

The thinner any solid body is, the more readily it expands by heat; thus, thin glass is not so liable to be cracked by hot water as that which is thick; cut glass therefore is easily cracked

The cause of the cracking of glass and china when put into hot water is their sudden expansion; thus they are more liable to crack in cold than in warm weather, when the difference in the temperature of the atmosphere and that of the hot water is not so great. When a china tea-pot is used in cold weather, luke-warm water should be put into it before boiling water. Glass tumblers and china cups should not have boiling water poured upon them in frosty weather.

Why does a clock sometimes go too fast in very cold weather?

Why does a piano or harp when tuned in a cold room, appear out of tune when the room is warmed?

How can a glass stopper fitting tight in the neck of a decanter be taken out?

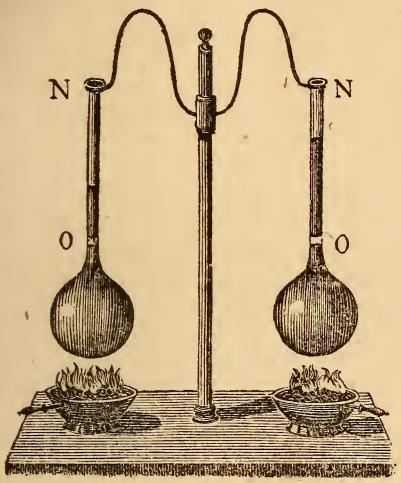
Why is thin glass less liable to be cracked by hot water than that which is thick?

Why does glass and china sometimes crack when put into hot water?

Caloric expands *liquids.*

Liquids expand more readily than solids, as the cohesive attraction in the former class of bodies is less strong, and caloric can pass more freely among their particles.

Some liquids are more expansive than others.



Experiment. Fill two globular glass vessels as far as to *o, o*, the one with alcohol the other with water; place under each a pan of burning charcoal. Both liquids will rise into the necks of the bottles but the alcohol will rise higher than the water.—The same principle may be illustrated by immersing two glass bulbs, the one containing water and the other alcohol, into a vessel of hot water.

Molasses, wines, and other fluids, being expanded by heat, the same quantity will occupy more space in summer than in winter; thus it is more economical to buy them in winter.

Caloric expands *gases.*

As the particles of gases are very little influenced by cohesive attraction, caloric easily insinuates itself among them.

Why do liquids expand more readily than solids?

What experiment shows that different liquids have different degrees of expansibility?

Why is it more economical to buy liquids in winter than in summer?

Why are gases much affected by caloric?

When a fire is made in a stove or fire-place the air of the room immediately begins to grow warmer, it expands also and becomes lighter; the warm air escapes in all directions through cracks in the doors, windows, &c., and cold air rushes in to supply its place.

Children who are fond of roasting eggs learn that it is necessary to crack the shell slightly, or it will burst with an explosion; this is in consequence of the expanding of the vapor within, which escapes when it can find vent; but if confined, bursts the shell by the expansive power of heat.

Another amusement in which children sometimes indulge, is that of blowing air into bladders and observing the effect which heat has upon them—this is a chemical experiment. If a bladder be tied tight at the neck although it should contain so little air as scarcely to swell it, yet when held to the fire it will expand until it bursts; if withdrawn from the heat before that takes place and put into a cold situation, it contracts. The addition of caloric expanded the air, the loss of it reduces its bulk.

Experiment.—Let the tube of a glass bulb having in it a small quantity of water, be inverted in a vessel of water. Apply the heat of a lamp to the bulb, caloric will pass into it and expand the air, and this forces the water down the tube. Remove the lamp, and as the air contracts, the water rushes back into the bulb.

Explanation.—When the tube was inverted, the water by its gravity was forced downwards, and air took its place. Caloric

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What changes take place with respect to the air when a fire is made in a room?

Why are the shells of eggs cracked, before they are put into a fire to roast?

What is the effect of heat upon bladders containing a small portion of air?

By what experiment is the expansion of air shown?

being applied to the bulb, penetrated it and expanded the air so that the water was forced farther down the tube, as soon as the heat was withdrawn and caloric began to pass off into the atmosphere, the air contracted and made room for the water to return again.

The expansion of air is eight times greater than that of water, and that of water forty-five times greater than that of iron.

We have learned that solids, liquids, and gases are expanded or enlarged in bulk by the addition of caloric, and that they shrink, or are condensed by the loss of caloric.

There is one remarkable exception to this law of nature—water though it expands by heat until it becomes a mere vapor, which we call steam, does not condense by the loss of heat, beyond a certain point. On the contrary, when water freezes, its bulk is found to be increased, as many a housewife has known to her sorrow, when she has found her earthen pitchers or glass tumblers cracked, by being suffered to stand full of water, exposed to a freezing atmosphere.

You can very easily satisfy yourselves that water expands in freezing, by filling with it a tin basin, and letting it stand exposed to the cold of a winter night: you will see the ice swelled out considerably above the surface of the basin.

It appears a wonderful provision of the Almighty for the preservation of man and animals that water should

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How is this experiment explained?

How does the expansion of air compare with that of water, and that of water with that of iron?

What have you now learned respecting solids, liquids, and gases?

What exception is there to this law of nature?

How can you learn that water expands in freezing?

What appears a wonderful provision of the Almighty for the preservation of man and animals?

be the only substance which does not continue to contract by the loss of heat.

If this were the case, when ice began to be formed in seas, lakes, and rivers, it would sink to the bottom, and by its coldness hasten the freezing of the upper portions of water until the whole mass would be one solid body of ice. The fish must then all die. The heat of one summer would not be sufficient to melt such an immense quantity of ice; and thus it would go on increasing from year to year, and extending farther and farther, until the very seas of the equator would present a solid mass of ice, and the influence of this upon the land would be so chilling as to destroy all animal and vegetable life.

Such would be the case had not the Creator made this *one exception* to the general law. Ice is lighter than water; indeed water begins to grow lighter a little before the freezing process commences; thus the ice remains upon the surface, preserving the water below from the influence of the cold air, so that it is a comfortable abode for its vast multitudes of inhabitants. How wonderful are the ways of Providence!

CHAPTER VI.

Thermometers. Conductors of Caloric. Evaporation.

We are now prepared to consider the principle on which the *thermometer* is made. It is probable that most who study this book know what a thermometer is,

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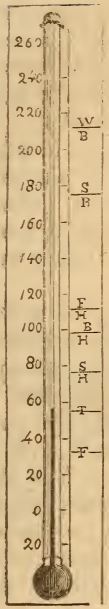
What would be the result if water continued to grow heavier by the loss of caloric through all degrees of temperature?

Why does ice remain upon the surface of the water?

What are we now prepared to consider?



and the uses for which the instrument is valuable, but some may never have seen or examined one. The figure will show you a thermometer; and we will endeavour to explain the principle on which it is constructed.

The word thermometer is derived from the Greek, *therme*, heat, and *metron*, measure. This instrument is used for measuring the degrees of heat. It consists of a hollow glass tube, having at one end a small bulb or hollow glass ball. The bulb and part of the tube contain mercury, above the mercury there is a vacuum, that is the tube is empty, it contains no air; this vacuum is caused when the thermometer is made, by boiling the mercury, and closing * the end of the tube. The mercury condenses on cooling, and thus leaves a vacuum in the tube. The rising of the mercury shows an increase of heat, its falling shows a diminution of heat, and the quantity which it rises or falls denotes the proportion of increase or diminution; this is pointed out by the figures standing for degrees which are marked on the frame of the thermometer.

The thermometer represented in the figure, and the one most commonly used in this country, is that of Fahrenheit, a German chemist. The *o* is called zero; all degrees of cold below this, are said to be so many degrees below zero. At thirty-two degrees (expressed

* That is, it is *hermetically* sealed; which means to close the end of a glass vessel while it is in a melted state. The term *hermetic* is derived from *Hermes* or Mercury, who was considered as the father of Chemistry.

What is the thermometer used for?
Describe Fahrenheit's thermometer.

32°) water freezes. This is marked on the figure by F. Between 50° and 60° (see F on the figure,) is temperate. Summer heat (marked S. H.) is a little below 80°. Blood heat (marked B. H.) is at 98°. Fever heat is 112°. Spirits boil at 176°. Water boils at 212°.

If the bulb of the thermometer were plunged in boiling water, the mercury would rise to 212°; if plunged into melting snow or ice it would fall to 32°. What was said with respect to the expansion of bodies by heat, will help you to understand the cause of the rising and falling of the mercury in the thermometer.

The thermometer is of great use not only to scientific men in their experiments, but for many common purposes. The apartments of the sick should always be of the same temperature; and to regulate this, a thermometer is necessary. It is needed by gardeners to regulate the temperature of their greenhouses. It assists the navigator, informing him by means of the increased coldness of the water, when he is approaching land, soundings or shoals; especially warning him against the icebergs so common in northern latitudes; on the contrary when approaching the Gulf-Stream the water becomes warmer.

There is another kind of thermometer, which we will now describe; it is called an *air thermometer*, because it operates by means of the expansion of air. The figure represents the air thermometer of Sanctorius an Italian physician, of the seventeenth century; this was the first of the kind which was invented. The egg-shaped vessel with a long neck is called a *matrass;* this is supported, with its neck downwards, by a ring and an upright wire; the tube is open and extends below the

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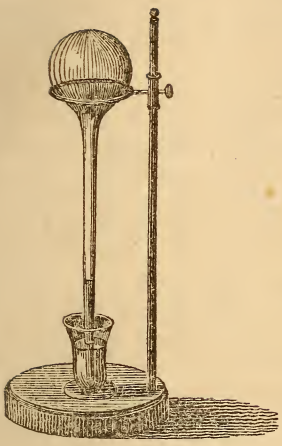
What effect do boiling water and ice have upon the thermometer?

What are some of the practical uses of the thermometer?

Describe the air thermometer.



surface of the water into the cup beneath. On holding any heated substance near the matrass, the air being expanded, a portion of it escapes through the water of the cup; on removing the heat, the air condensing in the matrass, receives water into the neck to replace the air which escaped. Now when heat is afterwards applied, the air which remains in the bulbous part of the matrass, in expanding, forces the water lower down in the neck. If ice were applied, the air condensing would admit a still greater portion of water into the matrass.

Air thermometers are useful in determining those slight differences of temperature, which would not materially affect the mercurial thermometer; for you will recollect that as gases are more expansible than any other bodies, air will be sooner affected by heat than mercury.

There is another kind of air thermometer which is generally preferred to that of Sanctorius; this is shown by the figure. It consists of a glass bottle containing a small quantity of coloured water; the bottle is closely corked, so that the air within cannot escape; a very small glass tube is fitted into the cork, and extends down so as to pass into the fluid. On applying heat, the air in the bottle being expanded, presses upon the liquid beneath it and forces a portion up the tube. The height of

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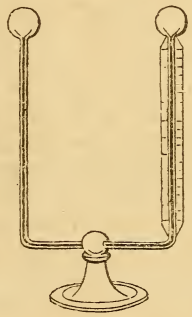
For what are air thermometers useful?
What does the figure represent?

the fluid shows the expansion of the air, or the degree of heat to which the air thermometer has been subjected.



There is still another kind of thermometer; it is called the *differential* thermometer, because its use is to determine the *difference* of temperature in any two bodies or places. It has two bulbs, as you see in the figure; its tube is partly filled with some coloured liquid while the remainder is filled with air. When both bulbs are exposed to an *equal* temperature, the fluid in the tube remains unmoved, but if one bulb is exposed to more heat than the other, the fluid will rise towards the opposite bulb. This is on account of the expansion of the air, which, pressing upon the liquid, causes it to remove.

The *barometer* is used for ascertaining the weight of the atmosphere; the mercury in that instrument rises when the pressure of the air is greatest, and falls when it is least; never lower than about *twenty seven* inches, nor higher than about thirty three inches. A column of air forty-five miles high, is supposed to be of equal weight to a column of mercury thirty inches high, and a column of water thirty three feet high.

CONDUCTORS OF HEAT OR OF CALORIC.

Caloric has a constant tendency to pass from one body to another, that is to go from a substance containing more, to one that has less, until both shall be of an

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Describe the differential thermometer.

For what is the barometer used, and on what principle does the mercury in that instrument rise?

What is remarked of the tendency of caloric to produce an equilibrium?

equal temperature, or as chemists would say, until an *equilibrium* between the two is produced.

Suppose that one person having very cold hands takes the warm hand of another person—you can imagine the very different sensations which each would experience. The one says, 'how cold your hand is,' the other, 'how warm.' Caloric leaves the warm hand to go to the colder one which comes in contact with it; this causes the sensation of cold to the person who loses caloric, while the one who gains it, feels the sensation of warmth.

But let a healthy person having a warm hand take the burning hand of one in a fever, and the latter will seem hot, while to the sick person, the hand of the other will appear cool.

If the door of a warm apartment be opened into a colder one, the warm air rushes out, and the cold enters, until the two apartments are of an equal temperature.

Some substances *conduct* heat much more readily than others.

Experiment.—Take a pipe-stem and an iron wire of equal size and length, and stick to one end of each, balls of bees wax, of equal size: place these in such a situation that the ends opposite the wax will receive an equal degree of heat from burning coals. The wax on the iron rod will soon melt, while that on the pipe-stem will scarcely be affected by heat.

Explanation.—Both rods receive caloric, which passes from one particle to another, but with much greater rapidity from the particles of iron than those of the clay.

What takes place when one person, having cold hands, takes the warm hand of another?

How does the hand of a person in a fever appear to the warm hand of a healthy person?

What is the effect of opening the door of a warm room into a cold one?

Do all substances conduct heat in the same manner?

What experiment shows the difference in substances, as to their power of conducting heat?

Explain the experiment.

Take four small rods, metal, wood, glass, and whalebone, and cement one end of each to a ball of sealing wax; then let the opposite ends be equally exposed to heat; the metal will soon become so hot as to melt the sealing wax, the wood and whalebone will burn near the wax without melting it, and the glass may be heated so that it may be bent, without affecting the wax.

If you hold one end of a pin or needle in the flame of a candle, it almost instantly becomes so much heated at the other end as to burn the fingers. A glass rod of equal size may be held in the same situation, until the end in the flame melts with heat, and yet the other end seem little affected by it.

Such substances as feel coldest to the touch, are generally the best conductors, while those that in their ordinary state feel warmest are the poorest conductors. Thus metals are good conductors, while feathers, wool and hair are poor conductors.

Bodies conduct heat with less facility when their parts are spongy and divided; thus iron filings are poorer conductors than an iron bar of the same weight; this is supposed to be owing to the existence of air between these parts, and air is a poor conductor.

What is the second experiment for illustrating the principle we are now considering?

What different effects would you perceive on holding one end of a knitting needle, and one end of a glass rod of the same size in the flame of a candle?

What substances are generally the best and what the poorest conductors?

Why are iron filings a poorer conductor of heat than an iron bar?

Stones are not as good conductors of caloric as metals—bricks are poor conductors, and for this reason when heated and wrapped in a cloth, they are useful for keeping the feet warm in cold weather; but a heated piece of plank is still better, because wood conducts or loses caloric less easily than brick.

Wool, hair, and fur, are poor conductors of caloric. Thus we find that the animals of cold countries are protected against the severities of their climate by their covering. These are not warm in themselves but they keep the animal heat from escaping into the cold atmosphere.

We speak of particular garments being warm, but this is incorrect; the less readily substances conduct heat, the warmer they keep our bodies by preventing their caloric from passing off. The looser the materials of which garments are made, the warmer they will be; thus quilted under garments containing a slight quantity of cotton, are much warmer than the same weight of a cloth of firmer texture. Our good grandmothers used to labor hard to manufacture thick and heavy woollen blankets and coverlets; but we have learned that two thicknesses of calico, quilted with a few pounds of cotton between, make a bed-covering much warmer, lighter, and cheaper than the carpet-like blankets of former days.

The finer the fibres of substances are, the less do they serve as conductors of caloric; thus the animals of cold countries are furnished by their Creator with finer and softer feathers, wool, and fur, than those of warm countries; indeed if the latter animals are carried to frigid regions, He who gave them their cover-

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What is said of stones and bricks as couductors of caloric?

Of what use are the wool and fur of animals in cold countries?

Are some garments really warmer than others, and if not, why are our bodies warmer when clad with them than others?

Why is it that the animals of cold countries are furnished with softer feathers, wool, and fur, than in hot countries?

ing, makes it to grow softer and finer that they may be protected from the cold.

Ice and snow are bad conductors of caloric; thus the ice in rivers and lakes protects the water below from freezing; snow is of great use in protecting vegetation from frosts and severe cold. When the snow comes early in the season, and remains late, the farmer expects a good crop of grain, but when there is not snow to protect it, it is often *winter killed.*

Liquids are not as good conductors of caloric as solids; in the latter the particles are fixed and transmit caloric from one to the other; when liquids are heating, the particles themselves are in motion, and carry caloric with them.

When a kettle of water is placed over the fire, the particles of the fluid at the bottom of the kettle first receive caloric, they expand, become lighter and rise to the top; the colder particles sink, and are in their turn heated and rise. This process continues until the whole is heated. The figure shows the heated particles rising and giving place to colder ones.

You will perceive, from the manner in which water becomes heated, that if a vessel of this liquid were placed *under* instead of *over* the fire, the lower portions of the water

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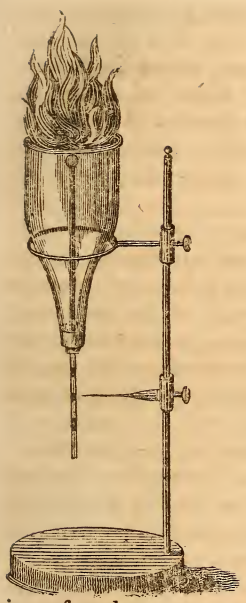
Are ice and snow good conductors of caloric?

What comparison is made between the conducting powers of liquids and solids?

What process goes on when liquids are heated?

What would be the effect of placing liquids under a fire instead of over it?



would not be heated; because the warm particles, being lighter, would still remain at the top.

This principle may be illustrated, as in the figure, by inserting into the bottom of a vessel of water an air thermometer, and burning ether or alcohol upon the surface of the water. The bulb of the thermometer, although within half an inch of the flame, will be unaffected by heat.

Gases are the poorest of all conductors of caloric.

The common air stops the progress of caloric more than any other substance. Why do people use a fan in warm weather? Because, when the air is set in *motion*, the warmer particles are driven away, and cooler ones take their place. These are pleasant and refreshing for the moment; but that they do not take away heat from us, is evident, from the fact, that the instant we cease to fan ourselves, we feel as warm as at first.

If, instead of cool air, we had been bathed with cool water, we should have felt our bodies sensibly cooled.

When air is heated, currents are produced. In a room where there is a fire, the air in the upper part is warmer than that in the lower part, because the particles which are warmed instantly rise, are cooled as they ascend, and then fall again; thus in a warm room there

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What does the figure illustrate?
Are gases good conductors of caloric?
What is the use of a fan in warm weather?
What produces currents of air?

is always an ascending and a descending current of air. If a door of a warm room be opened, hot air rushes out at the upper part, while cold air blows in below. This may be proved by holding the flame of a lamp at an open door; at the upper part, the flame will be blown outwardly, at the lower part inwardly, while midway, the flame will remain in its usual perpendicular position.

You can now understand the *causes of winds*, which are only currents of air; thus warm air being lighter rises upwards, while cold air, being heavier, presses downwards. In geography, you read of the *monsoons* of India; or of winds which blow six months from the south, and six months from the north;—the sun is six months in going from the equator to the northern tropic and returning; during this time the surface of the earth north of the equator is heated; the warm air rises, and cold air from the southern hemisphere rushes in to supply its place; this is a southerly monsoon; the northerly monsoon is in like manner produced when the sun is in the southern hemisphere.

The constant circulation both in the air and waters of the globe, is of vast importance to the comfort of man. In this way the hot air of the equatorial regions, is tempered by winds from cooler countries, and the heated waters of one portion of the earth, mingle with the cooler currents from the other.

EVAPORATION.

When you leave a small quantity of water in a tea-saucer or any open vessel, in a short time you perceive the dish is dry. Did you ever think what becomes of the liquid in this case? It passes into the air

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What causes the monsoons of India?

How does the circulation in the air and waters of the globe tend to the comfort of man?

What do you understand by evaporation?

in fine particles called *vapour;* thus we say it has *evaporated.*

Caloric is the great agent in evaporation; the warmer the weather is, the faster the process of evaporation is carried on. In very hot weather a floor that has been sprinkled with water will soon be dried, that is the water will have evaporated, and the air having parted with caloric will appear cooler.

In cities during hot weather persons are employed to go about the streets with large casks of water, which, by an apparatus contrived for the purpose, is sprinkled over the path as the cart which contains it moves slowly along. This not only prevents the dust from rising, but has a very sensible effect upon the atmosphere around, from which the water in evaporating withdraws a portion of caloric.

Physicians sometimes order persons sick with fevers to be wet with cold water, by means of a sponge applied to the face, chest and limbs; and cause this operation to be performed very frequently with water taken fresh from a well. In a few minutes a bowl of water thus applied to a person in a high fever will become warm from the caloric which it has gained. Such a process as you might naturally suppose, has a tendency to abate the fever; and though it may not remove the cause, it affords a temporary and refreshing alleviation.

The air always contains more or less moisture, some degree of which seems necessary to our breathing: when the air is unusually dry, we feel as if our lungs were parched, and we desire to drink often.

That the air contains moisture is shown by the appearance of a tumbler of cold water in a hot day. It

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What is the great agent in evaporation?

Why are the streets in cities sprinkled with water during the hot weather?

Why do physicians sometimes order their patients to be wet in cold water?

Does the moisture in the air seem necessary?

What shows that the air contains moisture?

will be covered by moisture or even drops of liquid; this cannot proceed from within, since the water does not penetrate the glass; it is caused by the condensing of the fine vapour of the air by means of the coldness of the tumbler.

You must by this time, if you have studied with attention the subjects which this book has presented you with, perceive that Chemistry is a vast science. It is now but in its infancy, and yet how many phenomena has it explained to the understanding of man, which were once either regarded with superstitious terror, or passed without observation! But we should neither superstitiously ascribe to miracles, changes which science can explain, or look with stupid indifference upon the operations of nature.

Society is now rapidly improving, and inventions by means of scientific principles and discoveries are fast following each other. Much of the labour which was once performed by men, is now carried on by machinery; this gives more leisure for *observations* and *experiments*, which are the only means of making farther discoveries.

When we examine the names of those who have benefitted the world by their discoveries, we find that practical mechanicians, those who have at the same time worked and studied, have done as much, even for science, as those who have been wholly devoted to the learned professions.

What do we perceive from the subjects already considered, with respect to the importance of Chemistry?

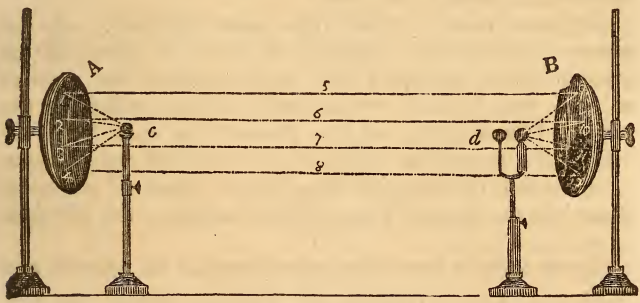
What gives opportunities for further observations and experiments in the sciences?

Who are those that have most benefitted the world by their discoveries?

CHAPTER VII.

Radiation of Caloric. Reflection and Absorption of Caloric. Freezing. Boiling. Sources of Heat.

We have seen that caloric is conducted from one particle of a substance to another, and that bodies differ in their conducting power. We are now to consider caloric as passing directly from one body to another by means of a power which enables it to dart forward without assistance from any intermediate substance. This is called *radiated* heat, because it passes off in rays, in the same manner as light is radiated.



A and B concave mirrors fixed on stands. *c* heated iron ball placed in the focus of the mirror A. *d* Thermometer in the focus of the mirror B. 1, 2, 3, 4 rays of caloric, radiating from the iron ball, and falling on the mirror A. 5, 6, 7, 8 the same rays reflected from the mirror A to the mirror B. 9, 10, 11, 12 the same rays reflected from the mirror B to the thermometer.

Experiment.—The figure represents two concave metalic mirrors fixed on stands; they are placed upon a

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What is meant by radiated caloric?
What experiment proves the radiation of caloric?

table at the distance of a few feet, and directly opposite. Now if an iron ball be heated almost to redness, and placed in the *focus** of one mirror, and an air thermometer be placed in the focus of the other mirror, the thermometer will be at once affected by the heat.†

Explanation.—Caloric was radiated from the heated ball in every direction, the rays lessening in intensity according to their distance from the ball; those rays which are intercepted by the mirror, are reflected back in right lines until reaching the other mirror, they are then reflected in a collected form upon the bulb of the air thermometer standing in its focus. The lines in the figure represent the course of the rays of caloric. 'It is a property of *concave* mirrors to render *parallel* the *divergent* rays received from its *focus;* and to cause the *parallel* rays which it intercepts to become *convergent* so as to meet in its *focus.*'

Surfaces which reflect light most perfectly, are not always best for the reflection of heat; a glass mirror placed before a heated ball would absorb the rays of caloric, and become warm itself, without reflecting the rays. Glasses are used to protect the eyes from the effects of intense heat during some chemical experiments.

If, instead of a heated iron ball, a mass of ice were placed in the focus of one of the mirrors, the air ther-

*By the focus is meant that point where all the reflected rays meet.

†In some books on Chemistry, an increase of temperature is said to be indicated by the *falling* of the air thermometer, in others by its rising; this is according as the thermometer of Sanctorius, or the other one described, on the same page, is used. The same principle by a different mode of construction causing different appearances.

How do you explain this experiment?

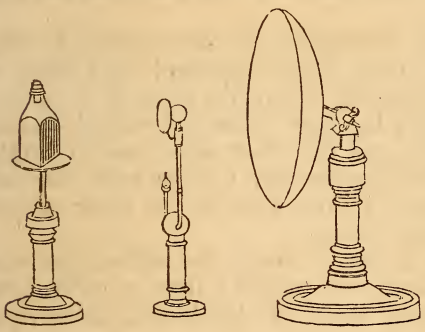
Are surfaces which reflect light most perfectly, the best for the reflection of heat?

What would be the effect if a mass of ice were placed in the focus of one of the mirrors, and an air thermometer in the focus of the other?

mometer in the focus of the opposite mirror, would show a diminution of temperature, or that it had lost caloric. You might from this suppose that cold was radiated like caloric, but in this case the radiation is from the thermometer itself, which is the hotter body, and parts with some of its caloric to the ice.

There is indeed no such thing as cold. Cold water contains caloric, the loss of a portion of which changes it to ice; ice contains caloric, for there are colder substances than this, as freezing mixtures of various kinds. Cold is a term denoting the absence of heat.

Polished or light coloured surfaces do not radiate heat as well as those which are rough and dark coloured.



Experiment.—The figure represents a square glass bottle placed opposite a concave metallic mirror. You are to suppose one side of the bottle to have been smoked with the flame of a lamp until completely blackened, and another side covered with tin; in the focus of the mirror is placed the bulb of a thermometer, having before it a little circular screen, to prevent any rays of heat from the bottle falling directly upon the thermometer. The bottle being filled with boiling water, the different sides are successively turned towards the reflector; the thermometer indicates the greatest increase of temperature by the blackened side, and the least by the metallic side, while the effect of the glass side is greater than the one, and less than the other.

Is cold a real existence?

Do polished or light coloured surfaces reflect heat as well as those which are rough and dark colored?

Explanation.—Rays of caloric from the bottle of hot water were thrown upon the mirror, which reflected them in a concentrated form upon the air thermometer placed in its focus. The blackened side parted with heat faster than the other sides, of course the thermometer denoted the greatest increase of caloric when that side was presented. The tinned side being bright and polished did not admit the rays of heat to pass freely through it, and thus when that was presented, the thermometer showed a lower degree of caloric. The glass side transmitted heat better than the polished tin, but not so well as the blackened and rough side, of course it affected the thermometer more than the one and less than the other.

An experiment illustrating the same principle may be performed in a more simple manner; by holding a thermometer successively before the sides of a tin canister, one of which has been scratched and blackened with lamp smoke, and the other sides remain bright and smooth. The thermometer will be more affected by the direct rays of caloric, than in the other experiment by the reflected rays.

The following statement shows the different proportions in which heat was radiated from a cubical tin vessel, one of whose sides was blackened, another papered, and another glazed:

The thermometer was raised by the

blackened	side	100 degrees
papered	"	98°
glazed	"	90°
bright metallic	"	12°

What experiment may be made to show the different powers of different surfaces to reflect heat?

Explain the experiment.

How may the same principle be illustrated in a more simple manner?

In what proportions are different surfaces found to radiate heat?

Those bodies which *absorb heat most readily*, radiate it most powerfully, that is, their *absorbing* and *radiating* powers are equal; a piece of iron heats soon, and parts with its heat readily; a brick neither heats as soon, or so quickly parts with caloric.

Radiation and *reflection* are found to be in an *inverse* proportion; that is, those bodies that *radiate* caloric most powerfully, *reflect* it least; thus, the reflecting mirror did not radiate heat which came from its own substance, but threw back the rays which fell upon it, as a hard substance causes the rebounding of a ball.

Some colours absorb caloric more readily than others. This may be shown by a very simple experiment. Take a piece of black woollen cloth, and another of the same size and quality of white or light coloured, and lay them upon the snow, when the sun is shining. In a few hours the black will be found to have sunk considerably below the surface of the snow, while the white will remain on the surface. From this we infer, that the black cloth *absorbed* caloric from the sun and gave it off in sufficient quantity to melt the snow beneath, while the white did not absorb caloric. You will recollect that black bodies absorb all the rays of *light*, while white ones reflect them all. But in the case of caloric, black substances not only absorb but reflect it, while with respect to light it does not reflect any of its rays.

FREEZING.

We have already remarked, that there is in reality no such thing as cold; what we call cold being merely the absence of heat. When we put our hand upon a

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What bodies radiate heat most powerfully?

How do radiation and reflection differ?

What is said of the difference in colours with respect to absorbing caloric?

What causes a sensation of cold when we put our hand upon ice?

piece of marble, or ice, we say 'it is cold'—we feel what we call a sensation of cold; but the sensation is caused by the loss of caloric which our hand experiences on coming in contact with a colder substance. You will remember the property of caloric to produce an *equilibrium*, and that a body which contains more heat, always communicates it to another which has less, when the two are brought together.

When *solids* become *liquids*, *caloric is absorbed from surrounding bodies.* You may easily prove this by putting your hand into a vessel of common salt and water; the salt, in dissolving, that is, in passing from a solid to a liquid state, absorbs caloric from the water and renders it so cold as to be painful to the hand.

Ice-creams, which it was formerly thought could only be obtained at a confectioner's, may be easily prepared in any family by the following simple process: put the cream, suitably prepared with sugar, &c., into a tin vessel, with a tight cover, and place this in a larger pail or tub, surrounded with pounded ice and fine salt; the edges of the cream will soon freeze; a spoon should then be introduced into the vessel of cream and remove the frozen part into the centre, and in the course of a few hours the whole will be frozen. The process should be carried on in a cool room, and the vessel of ice kept covered, to protect it from the caloric of the air.

You will scarcely need to have this experiment explained, since you understand that solids in becoming liquids take caloric from surrounding bodies. Ice alone would make the cream very cold, but would not, in melting, take away sufficient caloric to freeze it; but by adding another solid, viz. salt, which having a great affinity

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What is the effect upon surrounding bodies when solids become liquids?

How may ice-cream be prepared?

Why is ice alone not sufficient to freeze the cream?

for water, assists in bringing it into a liquid state, and is thus itself dissolved, more caloric is taken from the cream, so that its temperature is reduced below the freezing point; of course it becomes solid.

We have seen that solids in becoming liquids absorb caloric, and you must also have thought, from the example of the cream becoming ice in consequence of parting with caloric, that freezing is a process by which heat is given off; this is the case, freezing is a *warming process*, and melting is a *cooling process.*

Our winters would be much colder were it not for the freezing which is going on, and which, in changing liquids to solids, gives out caloric into the atmosphere.

The cold, chilly winds that are so common in the spring in our climate, are caused by the melting of ice and snow.

The caloric which exists in cold water is called *latent*, (from *lateo*, concealed,) because it is not perceptible to our senses.

When liquids become solids, heat is given out.

This may be illustrated by the slacking of lime, the water unites with the lime in a solid state, and much heat is pressed out; buildings have taken fire from the circumstance of water having accidentally been brought in contact with lime. As more caloric is necessary to keep a body in a liquid than a solid state, you can perceive the reason for the fact stated.

The same principle may also be illustrated, by adding to a small quantity of muriate of lime in a wine glass, a little sulphuric acid; both the substances are liquid,

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What are the different effects of warming and freezing upon surrounding bodies?

What prevents our winters from being colder than they now are?

What causes the cold winds of spring?

What is said of the caloric which exists in cold water?

What takes place when liquids become solids?

How may this be illustrated?

In what other way may the same principle be illustrated?

but they unite and form a solid sulphate of lime; so great a quantity of latent caloric is pressed out, that the glass becomes almost too hot to be held in the hand.

As ice becomes water by gaining caloric, water becomes steam or vapour by the same process. Put a piece of ice on a fire shovel and hold it over the fire, the addition of heat to the solid, soon changes it to a liquid; continue to hold the shovel over the fire, and the liquid soon disappears; it has gained sufficient caloric to change it to steam. The steam, by losing caloric, is condensed and becomes water, and that by losing still more caloric becomes ice again.

BOILING.

When liquids are united to a certain degree of heat, they are converted into steam or vapour; this process is usually attended with a bubbling noise and an agitation of the fluid, called *boiling.*

We have shewn under caloric, (see page 54,) that when a kettle of water is placed over the fire, the heat soon causes particles of the fluid to rise by rendering them lighter, while, at the same, there is a descending current of the colder particles; this process continues until the whole mass is heated to 212 degrees; a new operation then begins. The heated water at the bottom now re-

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How is ice affected by gaining caloric, and how may steam be changed to ice?

What is boiling?

Describe the process which goes on when water is converted into steam.

ceives more caloric, and becomes steam, or vapour, which passes off into the atmosphere, as you see in the figure. The water in the kettle is not raised above the 212°, but remains at this point until the very last drop has been changed to vapour. You will perceive by the figure, that the steam near the spout of the tea kettle is invisible, while it may be seen at a little distance; this is owing to its mixing with the cooler atmosphere which condenses it, and thus gives it the appearance of a cloud.

Vapour or steam is of the same temperature with the boiling liquid so far as indicated by the thermometer; which stands at 212 in boiling water, and the same in the steam which issues from it; but yet there exists in steam a much greater quantity of caloric, although in a latent state. As a large quantity of latent caloric is combined with water, a still greater portion is necessary to hold water in the gaseous state.

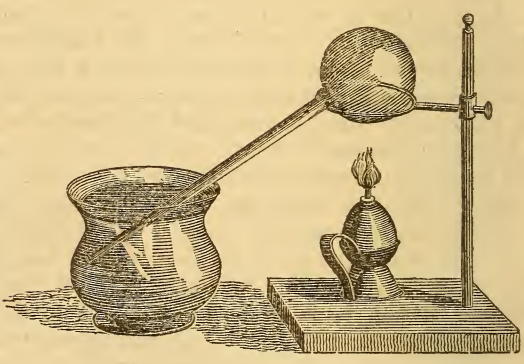
A celebrated chemist computed the heat of steam in the following manner: he noted the time necessary to raise a certain quantity of water to the boiling point, or 212°; he then kept up the same heat until the whole was evaporated, and marked the time consumed by the process. Allowing the increase of heat to continue in the same ratio, he estimated that the steam contained 810° of latent heat, or that this quantity was necessary towards keeping water in a state of vapour; this, added to the 212° of heat apparent by the thermometer, would make the actual caloric existing in steam, 1022°.

When steam is condensed, or when vapours return to their liquid state, their latent heat is rendered sensible; a small quantity of steam gives off a great portion of caloric.

The powerful heat of steam is experienced by those

Is there more caloric in steam than in boiling water?
How did a celebrated chemist compute the heat of steam?
What takes place when steam is condensed?

who accidentally hold their hands for a moment near the spout of a boiling tea kettle. The pain which ensues is very acute. Children have been known to die from inhaling into their lungs the least portion of steam, from the spout of a tea-pot of hot water. If such be the effects of the very least quantity of steam in contact with any portion of our limbs or our lungs, how awful must be the condition of those unfortunate persons, who, in the bursting of the boiler of a steam boat, are not only enveloped in an atmosphere of this powerful and dreadful vapour, but obliged at every breath to inhale it into their lungs!



This figure shows the manner in which steam causes explosions of steamboat boilers. You are to suppose the little glass bulb, suspended over the lamp, to contain a very small quantity of water, and to be hermetically sealed. The heat of the lamp converts the water into steam, the expansive power of which is so great, that the glass bulb would soon burst with a violent explosion, if the heat were continued. Had there been

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What is remarked of the powerful effects of the heat of steam in contact with our bodies?

What does the figure represent?

any way of escape for the steam, it would have passed off without bursting the glass vessel. The boilers of steamboats are usually of copper, and furnished with a valve, which can be opened as occasion requires, for the purpose of letting off the steam.

The degrees of steam are marked in such a way that the engineer can know what force is employed, and understanding the power of his steam engine, if he use due care, accidents will seldom happen, for when he finds the steam increasing too fast, he lets it off by means of the safety-valve. But should the engineer neglect this, and suffer more steam to be formed in the boiler than it can contain, you can at once perceive, by the experiment with the glass bulb, that the boiler must burst; for copper can no more resist the expansive power of steam than glass.

The Effect of Atmospheric Pressure upon Boiling.

We are surrounded on all sides by the atmosphere, or air; it is supposed to be about 45 miles in height; that is, that this distance on every side of our globe is occupied by this invisible and elastic substance. Thin and light as air is, yet it has weight; and it has been proved that a column of air 45 miles high is equal in weight to a column of water thirty three feet high, and a column of mercury thirty inches high.

As you will learn many particulars respecting this in Natural Philosophy, we shall only consider the weight or pressure of the air as it respects boiling of different substances.

Although we are not sensible of the fact, yet the air is pressing upon us, and upon all bodies on the earth, at the rate of about fifteen pounds for every square inch.

When liquids boil, steam in ascending has this

How does the engineer of a steam boat know how much steam is produced?

By what is our globe surrounded?

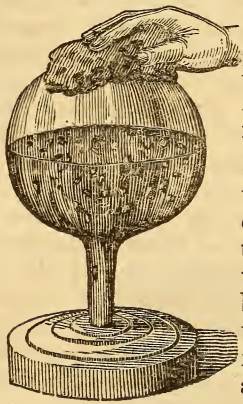
What are we now to consider with respect to the air?

What is said of the pressure of the air upon all bodies?

What has to be overcome when liquids boil?

weight of the air to overcome. When the atmospheric pressure is less than common, water boils at less heat than 212°, which is what is usually required.

As we ascend mountains the pressure of the air is less. At Mont Blanc, and upon the Andes, water was made to boil at a heat of about 180°. It is said, that for every five hundred and thirty feet of elevation, the boiling point is lowered one degree of Fahrenheit's thermometer.



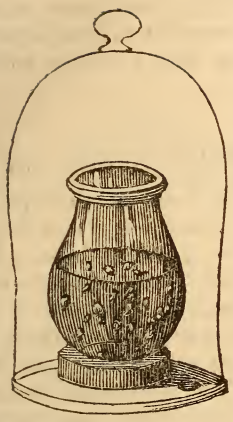
Experiment.—The following is a curious illustration of the effect of pressure in opposing the boiling process. You are to suppose a glass vessel half filled with water and closed perfectly tight, heated until it is entirely filled with steam; the boiling now ceases, but let the vessel be taken from the fire and apply a sponge wet with cold water, the liquid within begins to boil again. The process may be repeated; when the vessel is over the fire, boiling will cease, and continue to be renewed upon the application of a cold substance.

Explanation.—The vessel being filled with steam, its pressure prevented the farther boiling of the water. If it were to be kept for a short time in this situation, the increase of steam would burst the glass. On taking the vessel from the fire, and applying the cold sponge, the steam was condensed, and the pressure being thus removed, the boiling began again. This experiment shows that a lower temperature or less heat is required for boiling liquids when the pressure of the atmosphere is taken off.

What is said of the pressure of the air upon mountains?

What experiment illustrates the effect of atmospheric pressure in opposing the boiling process?

Explain this experiment.



The figure shows a vessel of water boiling under a glass vessel, called a bell-glass. You are to suppose the air has been all exhausted from the receiver by means of an *air pump*. The water heated to boiling, being withdrawn from the fire, the boiling ceases; on placing it under the exhausted receiver, the boiling again takes place, and will continue for some time.

The explanation of this phenomenon is the same as given for the last experiment, viz. the *pressure* is removed; in this case, it was that of the atmosphere; in the experiment previously described, the pressure removed was that of steam, which when condensed left a vacuum.

If *pressure* be greater than that of the atmosphere, more than 212° of heat will be required to boil water. Suppose a matrass, partly filled with water, and placed over a lamp, as represented in the figure. If the mouth is closed with the thumb, the water, though heated to 212°, will not boil, but the vapour created, will press upwards until it becomes difficult to keep the thumb over it. On removing the matrass from the lamp, and lifting the thumb from its mouth, boiling commences. This experiment

What does the figure represent?
What is the explanation of the phenomenon here observed?
What will be the effect when there is a greater pressure than that of the atmosphere?

shows that if the pressure of the atmosphere were greater than it is, a proportional increase of heat would be necessary in order to overcome this pressure sufficiently to boil liquids.

SOURCES OF HEAT.

The *Sun* is the great source of heat as well as of light. It radiates caloric in all directions; these rays may be collected by mirrors of a peculiar kind. In the focus of these mirrors a powerful heat may be obtained, sufficient to inflame combustible substances.

Combustion, or the burning of different materials, is the most important source of heat, next to the sun. It is by means of this that cooking of most kinds is performed, and that we are made warm and comfortable in winter, and are furnished with lights in its long evenings.

Did you ever think as you looked at the fire, and felt the warmth from it, what it is which creates the heat? Suppose that in a cold room some dry wood is laid in the fire place, and a spark of fire struck from a tinder box, makes a blaze; very soon the fire burns brightly and you begin to feel warmth. Yet the wood was cold, every thing in the room was cold, but now there is warmth.

We will explain this. By striking two pieces of flint violently together, caloric, which was latent in them, is brought into a free and active state; this, meeting with the dry combustible substance, unites with it and produces flame. The air furnishes caloric which exists in it in a

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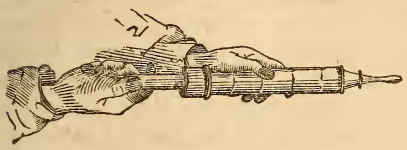
What is the great source of heat?
What is said of combustion?
What takes place when a fire is made in a cold room?
How do you accouut for the wramth which is produced by combustion?

latent state, but is pressed out by the process of combustion, and becomes *sensible* warmth.



That the air does contain *latent heat* may be proved by the use of a little instrument called a fire syringe, which is very convenient for lighting a fire. This consists of a small metallic tube, to which is fitted a rod and piston, as seen in the figure, A piece of *tinder* is fastened to the end of the piston; the rod is forcibly pushed to the bottom of the tube, and the tinder is set on fire. The tube was filled with air; on being compressed by the sudden moving the piston, the particles of air were brought so closely in contact with each other, as to force out caloric.

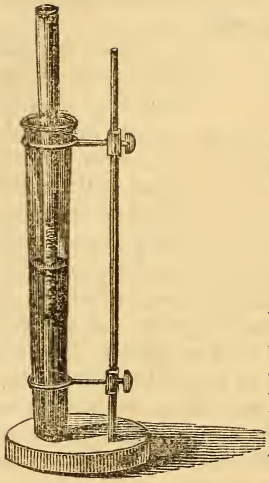
The *flame* which accompanies the burning of wood, oil, &c., is a subject about which chemists have entertained various opinions, and which seems still to be doubtful.

Combustion may proceed without flame; this is the case when any substance burns without being exposed to the air. Thus the timbers of a house beneath a brick fire-place have been known to become so much heated as to burn to a coal without the fire being perceived; had a column of air been admitted to the timbers thus consuming, a powerful flame must have been the consequence.

How can it be proved that air contains latent heat?

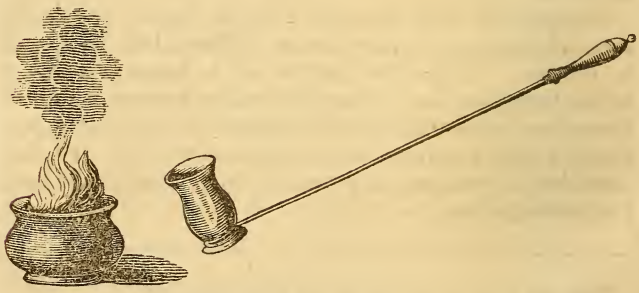
Is it easy to account for the flame which accompanies the burning of wood, oil, &c.?

Can combustion proceed without flame?



Chemical affinity produces heat; this may be so great as to produce boiling. The figure represents a longer tube containing coloured alcohol, placed within a shorter and larger tube; the latter should contain water reaching about one fourth as high as the alcohol in the inner tube; upon adding to the water about three times as much sulphuric acid, the alcohol will boil violently. Alcohol boils with less heat than water, but the experiment proves that a large portion of caloric is pressed out by the combination which took place between the water and sulphuric acid.

The figure below shows an instance of combustion by means of chemical affinity. The larger vessel contains a deep plate holding a quantity of alcohol; a very small



By what experiment is it shown that chemical affinity produces heat?

What does this experiment prove?

What is the lower figure designed to represent?

quantity of a solid substance called the *clorate of potash* is placed in the midst of the alcohol, a little sulphuric acid being then poured upon it, the flame bursts forth. The glass containing the sulphuric acid is fastened to the end of a rod because there is some danger from the explosion which takes place.

Besides the *sun*, *combustion*, and *chemical affinity*, there are other sources of caloric, *as electricity*, whose phenomena appear on a grand scale in a thunder storm, *percussion*, or the violent striking of hard bodies against each other, and *friction*, or the rubbing of substances.

By *percussion*, fire is struck from flint by steel, and carriage wheels, when in violent motion, strike fire from the stones in the path.

By the *friction* of dry leaves, or other dry combustibles, the Indians are said to obtain fire in the forests.

We have as yet said nothing of the cause of *animal heat*, for the subject is too difficult to be understood in this stage of your progress; and, indeed, the greatest philosophers find much difficulty in understanding the wonderful operations, which are carried on in the complicated machinery of living bodies. Although chemists are able to learn the composition of salts, minerals, gases, &c., they yet remain ignorant of what constitutes the principle of life in a plant, an insect, or a man.

Hitherto we have treated of subjects, which, from their nature, were somewhat abstruse, and, in some respects, calculated to confuse the mind. You will recollect that *affinity* is not a *substance*, but a *power;* and a power on which the science of Chemistry chiefly depends for its operations. *Light* and *Caloric* are *sub-*

What other sources of caloric are there, besides those which have been mentioned?

What is the effect of percussion?

How did the Indians obtain fire in the forests?

Is it easy to understand the causes which produce heat in animal bodies?

What general remarks conclude the chapter?

stances; they are called *imponderable*, because they are too delicate to be weighed by any balances which we have; indeed we cannot perceive them by any of our senses, not even by that of sight. Light, like our eyes, enables us to see other bodies, although it is itself invisible. Caloric is only visible by its *effects;* the flame which we see is only produced by the union of caloric with a combustible substance, aided by some principle contained in the air. The heat which we feel is only the effect of caloric entering our bodies.

CHAPTER VIII.

Electricity. Galvanism. Magnetism.

Electricity is an imponderable fluid, which we know only by its effects.

The word was derived from the Greek, *electron*, signifying amber, because it was in this substance that electricity, or a power of attracting light substances, was discovered.

The electric fluid is supposed to be diffused throughout the earth as extensively as caloric; and like caloric it seems to exist in a latent state, except when its equilibrium is disturbed.

You have probably observed on rubbing the back of a cat in the night, that sparks as if of fire appear, and you feel a prickling sensation in your hand. This is caused by electricity. Fur is one of those substances called *non conductors* of electricity, because instead of con-

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What is electricity?

What is the term derived from?

Is the electric fluid extensively diffused?

What causes the sparks which appear on rubbing the back of a cat in the night?

ducting off the electric fluid, it is capable of accumulating it, and becomes *electrically excited.* In this situation it gives off electricity, which is manifested by the sparks and the sensation it excites.

Another familiar example of the effect of the electrical fluid may have been noticed by you. When taking off clothing of silk or woollen which has been worn near the skin, sparks are often seen to come from it accompanied by a snapping noise. The garment having collected electricity from the body, gives it off when exposed to the air.

The hair often appears as if electrified, especially in cold weather; this is manifested by its standing erect, and appearing to fly back when the hand is placed near it.

But the grandest of all the appearances caused by electricity, is that which is witnessed in a thunder storm.

The state of the atmosphere, from some cause unknown to man, becomes, at times, especially during hot and sultry weather, such as to disturb the equilibrium of the electric fluid;—clouds are formed, some of which contain more electricity than others. When such clouds, containing different degrees of electricity, meet, the one which contains most, discharges the fluid. This discharge produces both the thunder and lightning; the latter is seen before the former is heard, because that light travels faster than sound.

We are able to estimate the distance of thunder from us by the number of seconds which intervene between the flash and report. Light moves with such velocity that we make no calculation for any time which passes between the discharge of the electric fluid and the appearance of the flash of lightning, but sound is supposed

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What other familiar example of the effect of electricity is mentioned?

What do we sometimes observe with respect to the hair, especially in cold weather?

What is the grandest exhibition of electricity?

What causes the discharge of the electric fluid in a storm?

How are we able to judge of the distance of thunder from us?

to move nearly at the rate of a mile in a second; therefore the number of seconds that pass after the lightning is seen, before the thunder is heard, shews how many miles distant the storm is. When we can count twenty or thirty seconds between the lightning and thunder, we suppose the storm to be about as many miles distant from us. When the report follows the flash almost at the same moment, we may know that the storm is very near us; and when persons are struck with lightning, the clouds bursting directly over their heads, the thunder and lightning appear at the same instant.

CONDUCTORS AND NON-CONDUCTORS OF ELECTRICITY.

It is of importance to learn what are *conductors* and what *non-conductors* of electricity, that we may take proper care in thunder storms not to expose ourselves unnecessarily. The *metals* are conductors—for this reason it is unsafe during a thunder storm which is very near, for people to wear spectacles with gold or silver bows, watches, thimbles, buckles in shoes, or indeed any metallic substance about the person—for when a house is struck with lightning, the *electric fluid* is usually conducted by the air down a chimney, or by the beams or walls into different apartments and will dart out of its way if a bright metallic substance offers itself as a conductor.

Feathers and hair are *non-conductors*—for this reason a feather bed or mattress is a safe position in a thunder storm. A seat upon a sofa or chair drawn out from the wall, with both the feet placed upon a stool is also one of the most secure against the approach of the electric fluid. An object is said to be *insulated* when surrounded by non-conductors of electricity.

Why is it unsafe for people in a thunder storm to have metallic substances about their persons?

What are the most safe positions in a thunder storm?

Glass being a non-conductor, it is safer to have windows closed in a thunder storm, than open.

But after all our care, (and it is proper that we should use all the means in our power for our own preservation), we must ever reflect that life is in the hands of Him who gave it. He can call up storms when we are travelling in the open sky with no means of escape; and He can even cause the very laws which He has established over nature, to vary whenever it is His will to take the life of man in a peculiar way. Thus, at times, the most skillful physicians find their usual remedies powerless, or producing contrary effects from what they have in other cases observed. This shows us that it is God and not *nature* who governs the universe; since nature herself is made to bend to His will.

Buildings may generally be secured from the effects of the electric fluid, by means of what are called *lightning rods*. These are long rods of iron, being at the upper end pointed, while the lower end is placed in the earth. The lightning rod should be higher than the building; then if there be a discharge of the electric fluid from a cloud near the building, the metallic points attract it, and the rod conducts it downwards into the earth.

In general the conductors and non-conductors of caloric correspond to those of electricity.

THE ELECTRIC MACHINE.

The *electric machine*, as represented, in the figure, is constructed for the purpose of showing many curious experiments which may be made by accumulating the

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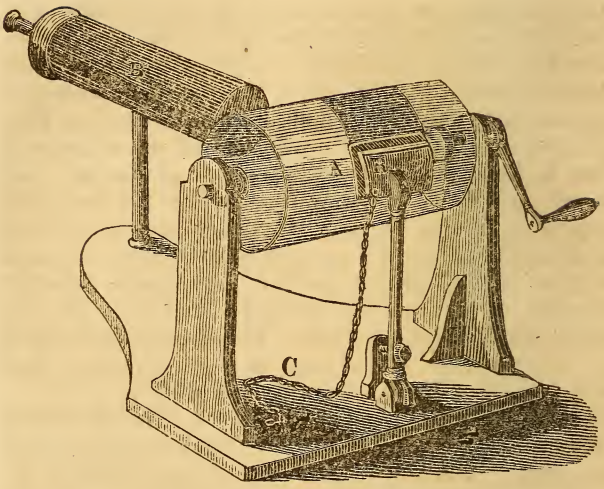
Why is it more safe to have windows closed in a thunder storm than open?

What reflection is here made?

How may buildings generally be secured from the effects of electricity?

Describe an electric machine.



electric fluid. This machine consists of two principal parts, a *glass cylinder* A, so fixed that it may be turned by means of a wheel, and a *conductor* B, which is either composed of some metal or of wood coated over with metal; besides these parts is the *rubber* R, which is a piece of silk hanging loosely over the cylinder and the *chain* C, which falls from the rubber to the ground. By turning the cylinder rapidly, the rubber gives off electricity and again receives it from the earth by means of the chain. The cylinder, being supported by glass legs which are non-conductors, does not give off its electricity until some *conductor* is presented; the metallic cylinder, being placed in contact with the glass, receives the electric fluid as it is accumulated by means of the friction with the rubber.

If a person place his hand upon the knob of the prime conductor, opposite the glass cylinder, when it is

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How are electric shocks received from the machine?

thus charged with electricity, he receives a severe shock; if many persons take hold of hands, thus forming a long line from the one touching the prime conductor, each one would feel the electric shock, and apparently at the same instant as it was felt by the person next the conductor.

The Electrophorus (or bearer of electricity,) is a very simple machine which was invented by an Italian chemist, Volta, and which may be used for illustrating many of the phenomena of electricity. It consists of two plates of wood, two or three inches thick; the lower one is covered with a mixture of sealing wax and resin, which are *non-conductors*, but capable of a high degree of electrical excitement; the upper plate is covered with tin foil, a conductor of electricity, and to this is attached a handle of silk which is a *non-conductor.*

The lower plate may be excited in various ways; fur being an important agent in accumulating the electric fluid, is generally used. After rubbing the resinous plate, let the other be placed over it, at the same time touching it with the finger, and the metallic, or upper plate, will be found charged with electricity.

POSITIVE AND NEGATIVE ELECTRICITY.

When a body contains more than the usual quantity of the electric fluid, it is said to be in a *positive state*, when less, in a *negative state.* These two states are sometimes expressed by the terms *plus*, more, and *minus*, less.

Opposite electricities *attract*, while *similar electricities repel* each other; that is, a body in a *positive state, attracts a body in a negative state;* while two bod-

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Describe the Electrophorus?

How is the lower plate excited?

When is a body, with regard to electricity, said to be in a positive and when in a negative state?

What is said with respect to the attraction and repulsion of opposite and similar electricities?

ies, both in a positive, or both in a negative state, *repel* each other.

A stick of sealing wax, or a glass tube, rubbed with a silk handkerchief, are in a different state of electricity from the surrounding bodies, and will attract light substances if presented to them. If some little balls of pith, suspended by a fine thread of silk, be presented to a body which is *electrically* excited, the balls will at first be attracted towards it. If one ball be brought in contact with the excited substance, and the attempt made to suspend it by the side of the other balls, it will be repelled.

The cause of this is, that the one ball acquiring from the excited electric, a new portion of electricity, communicates a portion of it to the ball which it touches, and thus they are both excited, and, like two persons under the influence of angry feelings, mutually repel each other. But if one of the balls in this situation be touched with the finger, it will give off its electricity and return quietly to its companions.

The mere *contact* of different metals, and of many other substances, produces *opposite* electrical states.

GALVANIC ELECTRICITY.—*Its Discovery.*

There is a mode in which electrical phenomena may be produced, called *Galvanism.* This is so named from Galvani an Italian, who near the close of the last century, discovered that the muscles and nerves of dead animals may be excited by the electric fluid; or, rather, this is said to have been the discovery of Madame Galvani, who being in her husband's laboratory or place for chemical experiments, accidentally observed convulsions in a dead frog which chanced to lie near the electrical machine, when in action.

Give some exemples of attraction and repulsion.
How do you explain these cases of attraction and repulsion?
What produces opposite electricities?
What can you say of the discovery of galvanism?

On examination by the professor, it appeared that a knife, in contact with the machine, had touched one of the legs of the frog; and that when any other metallic substance touched a nerve of the animal, a spark from the electric machine always produced a twitching of the limb.

Since then, many discoveries have been made of the astonishing effects of galvanic electricity. Some philosophers have been so enthusiastic as to believe that the dead might be restored to life, by its power. Various experiments have been made upon the dead bodies of criminals; and although terrible and appalling contortions of the frame, and frightful changes of countenance were produced, still it had not the power to restore life, for, as soon as the galvanic action ceased, its effects disappeared.

When two metals are connected by some substance capable of exciting their different electricities, galvanic effects may be observed. For instance, take a piece of silver and a piece of zinc, place the silver upon, and the zinc under the tongue, and bring their edges together at the tip of the tongue; you will instantly perceive a singular metallic taste, a slight twitching of the nerves of the tongue, and a flash of light.

Place a piece of silver on one of zinc, and a worm on the silver, and it will not be affected; but if it be brought in contact with the zinc and silver at the same time, it will writhe as if in distress.

Acids of various kinds, and water are found useful in promoting the developement of electricity in metals; thus the moisture of the tongue in the limbs of the

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What seemed necessary to be brought in contact with the nerve of a frog in order to produce a motion in the limbs?

What is said of experiments which have since been made, of the different applications of galvanism?

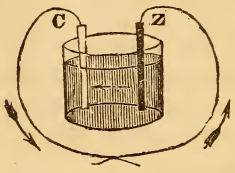
What case is mentioned in which silver and zinc produce galvanic effects?

How may a worm be made to show the effects of galvanism?

the skinned frog, and in the substance of the worm, were essential in producing the galvanic effects which have been described.

GALVANIC CIRCLES.

The cut represents a vessel containing an acid, much diluted with water, and two plates, the one of zinc, the other of copper, as shown by the letters *z, and c;* to each plate is soldered a piece of wire, which meet in the centre, opposite the place of insertion. This is called a *simple galvanic circle.* It is supposed that when in operation, there is in such a circle, a continual current of electricity, flowing in the direction of the *arrows* which appear in the cut, from the zinc to the fluid, from the fluid to the copper, and from the copper, back to the zinc. When the wires do not communicate with each other, the galvanic circle is said to be broken;—the wire attached to the copper plate is negative, and that attached to the zinc plate positive; the wires are also called *poles*, thus we say the copper is the *negative pole*, and the zinc the *positive pole.*



A *compound galvanic circle* consists of many *simple circles*, by means of which a powerful action is produced.

The *Voltaic pile* is so named from an Italian chemist, Volta. This is made by placing pairs of zinc and copper plates, one above another. Here we have a series of simple circles; between each pair of plates is placed a piece of cloth, wet with a weak acid. The

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What substances are found useful in promoting the developement of electricity in metals?

What is meant by a simple galvanic circle?

What is a compound galvanic circle?

How is the the Voltaic pile composed?

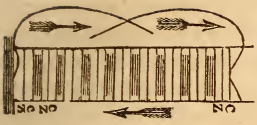
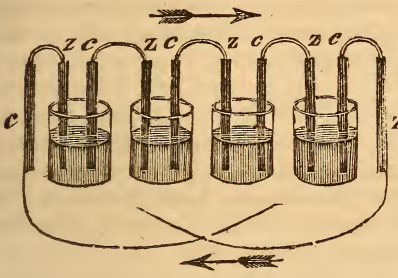


figure shews you a *Voltaic pile*, commencing with zinc *z*, and ending with copper *c*. The wires which meet in the centre are two poles. The arrows show by their points the direction of the electric current.



The *couronne de tasses** is a galvanic circle in which the acid solution is contained in separate cups. Each cup contains a pair of plates, and each zinc plate is attached by a wire, to the copper of the next pair. These cups, by being multiplied or diminished in number, increase or lessen the action of the galvanic fluid.

Dr. Hare of Philadelphia, who has done much for the honor of American science, has invented an apparatus called a *calorimoter*, or mover of caloric. It is very powerful in exciting heat, while its power of exciting electricity is comparatively small. Another and more important invention of Dr. Hare is his *deflagrator*, or an instrument exceeding all others in its power to burn metals, and those substances which resist all the ordinary effects of heat. As you advance in your knowledge of Chemistry, you will find, in the construction and operation of these instruments, much to admire.

*Pronounced couron-de-tas; meaning crowns of cups.

Describe the Couronne de Tasses.

Is heat always accompanied by the same proportions of electricity?

It has recently been maintained by chemists, that electricity was the great agent in all cases of chemical affinity, and combination. You will recollect, in considering the subject of affinity, we found that substances most unlike, unite the most readily, as in the case of an acid and alkali. Now we find these substances to have opposite electricities, and that opposite electricities do attract one another; therefore, the inference is in favor of electricity, as being the great connecting link in the chain of the material creation.

MAGNETISM.

There is a form in which electricity appears, called *magnetism.* The power of the *magnet* to *attract* and *repel* bodies, appeared mysterious, until discoveries in electricity, suggested the idea, that this fluid was the agent in the phenomena of magnetism.

Electricity when accumulated produces certain effects, many of which have been already laid before you. But the new appearances which magnetism exhibits are supposed to be owing to the electrical fluid *moving in currents* around the magnet.

The following are among the most important properties of the magnet:—1. It attracts iron and steel.* 2.

* I have just read an account of the power of the magnet, which cannot but interest the pupil. A young man engaged in some mechanical operation, unfortunately had a small sharp bit of steel fix itself in his eye ball. The pain which it produced was distressing; no relief could be obtained, and it was determined that he must submit to the operation of having his eye ball taken out in order to save his life. Some person suggested the use of the magnet—a powerful one being applied to the eye, the bit of steel left it and fastened itself to the magnet. Such are the benefits of science!

What is said of the connexion of electricity with Chemistry?

What has in some measure solved the mystery of the attraction of the magnet?

To what is magnetism attributed?

What are some of the most important properties of the magnet?

When allowed to move freely, it points towards the poles of the earth, and each end always points to the same pole. 3. The natural magnet has the power of imparting its properties to other bodies. 4. All magnets have a *north* and *south* pole.

You have heard of the *magnetic needle* or *mariner's compass.* It is by means of it, that the navigator, when upon the broad ocean, knows in what direction to steer his course; because the north pole, or end of the needle, points to the north pole of the earth, and the south pole, or end of the needle, points to the south pole of the earth.

Now supposing that there are currents of electricity constantly flowing around the globe; that a current from one end of the magnetic needle is attracted by a current from the north pole of the earth, and another from the other end of the magnet is attracted towards the south pole; this would explain the phenomena.

But we are to imagine that the currents from the north pole of the earth and the north pole of the magnet, are of opposite electricities, since such only attract each other. Thus we find that the north poles of two magnets repel each other; while a north pole of one, attracts the south pole of another magnet; from whence we learn, that *similar poles repel,* while contrary poles attract, each other.

The magnet, so called from Magnes, the discoverer, is familiarly called the *loadstone.* It is known in Chemistry as an oxide of iron; the natural magnet has the power of communicating its own properties to iron and steel, when brought in contact with them.

It has been discovered that the conducting wires of

How is the mariner's compass useful?

What reason may be assigned why one end of the magnet always points to one pole of the earth, and the other end to the other pole of the earth?

Do similar poles of the magnet attract or repel each other?

What is the substance called the magnet, and why was it thus named?

the galvanic circle communicate to some metals magnetic attraction; this seems to confirm the theory that magnetism is but a modification of the electric fluid.

If the imponderable agents, *light, caloric, electricity,* and *magnetism,* are not all essentially the same substance, appearing under different modes, they must be connected by some common tie, since they so closely attend upon and follow the steps of each other. Whatever these imponderable substances may be in their nature, or whatever bond of union may exist between them, we feel that they are mysterious and powerful agents operating within our own bodies, around us on every side; constituting the soul of material things, and keeping in action the elements of nature—and yet, after all, these are passive instruments in His hand who created them, and gave them laws.

CHAPTER IX.

Alphabet of Chemistry. Gases. Mode of collecting Gases. Oxygen.

You will recollect that the great object of Chemistry is to ascertain what things are made of, and how they are put together—we ought also to add another part of the office of Chemistry, which is to show what are the properties of bodies; that is, what *changes they are susceptible of themselves, and what changes they can produce in other bodies.*

What seems to confirm the theory that magnetism is the same thing as electricity?

What general remark is made, respecting imponderable agents?

What are the two important objects of Chemistry?

The teacher of Chemistry must proceed with his pupil, like one who teaches a child to read. We should expect he would first teach the alphabet of letters, out of which, words and sentences are made. The pupil in Chemistry must learn his alphabet, before proceeding to the compounds which are formed with it.

The alphabet of Chemistry consists of about *fifty simple* substances, called *elements.*

The ancients considered that there were but four simple elements, viz: fire, air, earth, and water. The three latter, are now known to be compounds; while the list of simple elements is increased by substances of which the ancients knew not even the existence, and by others which they considered compounds.

Among the substances unknown to the ancients, are *gases*, which do not exist in nature in a separate form, but are obtained, by being disunited from their combinations, by chemical means. Among the simple elements supposed by the ancients to be compound, are the metals.

By the *alchymists* of former days, a set of men, who, with some vague ideas of chemistry, were wholly ignorant of its true principles, it was thought that the less valuable metals, such as iron, lead, &c. might be so reduced and purified as to produce gold.

The alphabet of Chemistry, or the *simple substances*, of which the science treats, may be arranged as follows:

1. *Imponderable agents.* 2. *Ponderable substances.*

These consist of

1. *Metals*, about	40	
2. *Combustibles*, (not metallic)	7	
3. *Supporters of Combustion*,	5	perhaps more.

How ought the teacher in Chemistry to proceed?
What does the alphabet of Chemistry consist of?
What was the opinion of the ancients in respect to *elements?*
What substances were unknown to the ancients, and what simple substances did they consider compound?
What is said of the alchymists?
How may the alphabet of Chemistry be arranged?

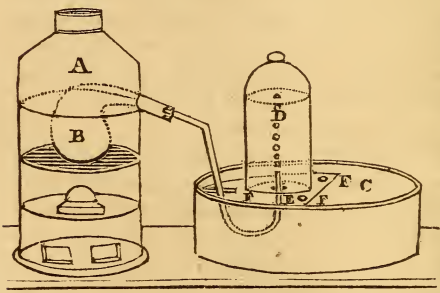
By the various combination of these 52 substances, every material thing on earth is formed; as are all the words used in our language, formed of the 24 letters of our alphabet.

GASES.

Among the simple elements is a very important class of substances, called gases. The term *gas* is derived from the German, and signifies *spirit;* it is applied to all æriform fluids, except the atmosphere, which is called, by way of distinction, the air.

Some gases are lighter, others heavier than the air. Some promote combustion, others extinguish it. Some are coloured, as red and green; others are white and invisible like the air. Some are destitute of smell, while others throw off offensive or suffocating odours.

MANNER OF COLLECTING GASES. EXPLANATION OF THE PNEUMATIC CISTERN.



Some gases are collected through water; others which have an affinity for water, and readily mix with it, are collected through mercury. Should some of the pupils who use this book, not have the advantage of seeing chemical experiments, as they proceed in their study, they may obtain an idea of the manner in which gases are collected, from the figure here presented. A represents a furnace; B, a retort, containing the substance which furnishes the gas; C, Pneumatic cistern; D, receiver; E, F, shelf. Through the centre of the cistern, is a narrow piece of board forming a shelf, above which the water of the tub rises a few inches. The shelf

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What is meant by a gas?

What comparison is made between the gases?

Describe the pneumatic cistern, and the method of collecting gases over it?

has holes through which the necks of gas bottles may be introduced;—sometimes wide mouthed vessels, such as bell glasses are used, in which case the vessel can rest upon the shelf, and but part of the mouth extend beyond the sides of the shelf. Now suppose we wish to collect some kind of gas—if we should introduce it into a vessel empty of any thing else, yet filled with the common air, (which penetrates every unoccupied space,) the gas would mix with the air, and be impure, or its qualities destroyed. For this reason the vessels which are to receive the gas are filled with water, and placed in an inverted position on the shelf, as appears in the figure. If any air, or gas is now introduced into the water, under the mouths of the vessels, it will ascend in bubbles. Air may be thus introduced by plunging into the cistern a vessel, with its mouth down and just below the mouth of the inverted vessel. As the one vessel fills with water, air will be pressed out and will rise in bubbles into the other vessel; as fast as air ascends it takes the place of the water which gradually lowers until, if there is enough air introduced, the inverted vessel is filled with it. In this manner air may be emptied out of one vessel into another. Now if any kind of gas is introduced, in the same manner it may be collected in the inverted receivers. Those of you who can have access to a pneumatic cistern, should not fail to exercise yourselves in transferring common air from one vessel into another, and indeed of collecting gases where an opportunity presents. Any person can put a piece of board over a tub, and with water and two tumblers, may learn by practice, (the best of all methods,) how to collect gases.

Two things in this process may seem at first unaccountable to you; the manner in which the water remains in the inverted vessels, and the displacing of the water by the air which is introduced below. The water remains in the vessels, because the pressure of the atmosphere on all sides, supports it; and it would support an unbroken column of water thirty-two feet high, as in the case of pumps where water is brought upwards by first pumping out the air; the vacuum being instantly filled with water. The barometer which has been described,* is constructed on the same principle. The air or gas rises through the water because it is lighter; if oil were introduced below the mouth of the vessel of water, it would rise in the same manner, for that is lighter than water.†

* See page 50.

† *Note to teachers.* It is often difficult to explain in words very simple processes. The experienced teacher will always supply, by explanations and illustrations, any deficiency of the text book. The gas apparatus may be exhibited in a small cheap way, and it is an important lesson in natural philosophy to observe the suspension of a liquid, the ascent of air, and the consequent displacing of the liquid.

What two things in this process may at first appear unaccountable?

OXYGEN GAS.

The first gas, which we shall consider, is one that always exists in nature in combination with other substances, and can only be obtained by separating it from them. This gas is an important part of air and water. It is the great *souring* principle; that is, a large proportion of it combined with a substance produces an *acid*. United to sulphur it forms *sulphuric acid*, and cider by being combined with it becomes vinegar.

The name of this gas is *oxygen*. It is so called from the Greek *oxus*, acid, added to *gennao*, to produce, because it produces acids. Other names have been at different times given, such as *fire air*, because it is important in combustion, and *respirable air*, because it is a part of the atmosphere necessary to the support of animal life.

Oxygen may be obtained in various methods; that which is most common is, by heating a substance called the *peroxide of manganese*;—this is usually found in connexion with iron ore, to which it bears a resemblance.

An *oxide* signifies a union of a substance with a small proportion of oxygen; a *deutoxide*, denotes a greater proportion of oxygen; and a *peroxide*, the highest proportion of oxygen with which a substance can unite, without being an *acid*.

The *peroxide of manganese* is a substance composed of a metal called manganese, united to oxygen in the proportion of 100 parts of the former, to 56 parts of the latter. On the application of heat, caloric unites with

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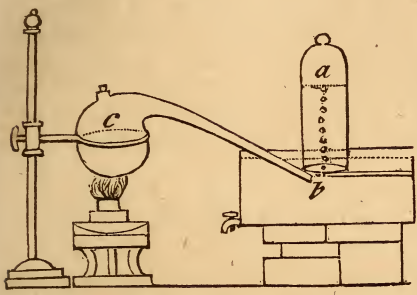
What is said of the first gas which we shall consider?
What is the name of this gas?
How is oxygen obtained?
What do you understand by the terms, oxide, deutoxide, and peroxide?
What is the peroxide of manganese, and what is the effect of heat upon it?

the oxygen of the metal and carries it off in a gas; so that oxygen gas is in reality composed of a base, oxygen, united to caloric.



The figure shows you an egg shaped vessel, called a *retort*, *c*, a pneumatic tub or cistern, *b*, having a *bell* glass, *a*, called a *receiver*, filled with water, and inverted over it. The retort is supposed to contain pulverized manganese, it is placed over a lamp, and its neck passes under the mouth of the receiver. As soon as the retort is heated to redness, oxygen gas begins to pass through the tube; at first it is impure, being mixed with the air which was in the retort; therefore the first gas that comes over should be suffered to pass into the cistern; in a short time all the atmospheric air being expelled, pure oxygen will appear. The neck of the retort being then placed in a suitable position, large bubbles of the gas will pass rapidly up and displace the water in the receiver. When the gas ceases to issue from the retort, the manganese has parted with all the oxygen that may be expected. What remains in the retort will be a *deutoxide of manganese.*

One pound of the peroxide of manganese, if good, will furnish from four to five gallons of oxygen gas. Red lead, which is a deutoxide of lead, is often used for collecting oxygen gas in the same manner as we have

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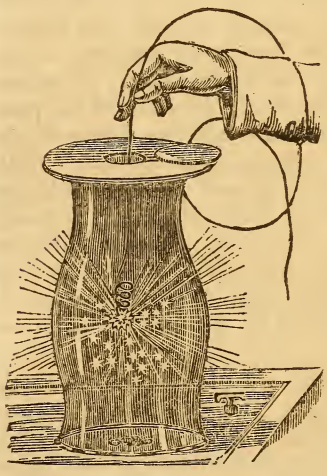
Explain the process of obtaining oxygen gas, as represented by the figure?

just described. Vegetables give off oxygen when acted upon by the sun's rays; though in the dark they exhale an unhealthy gas, called *carbonic acid gas.*

Having obtained oxygen gas, there are a variety of beautiful and interesting experiments which may be made with it—these experiments show us the nature and properties of this wonderful substance. We say substance, because, although we can neither see, smell, nor taste it, it is one of the a most powerful and active agents in nature.

The properties of Oxygen Gas.

1. Oxygen is the great *supporter of combustion;*—that is, its presence and aid are necessary to the burning of substances.



Experiment.—We will suppose the glass vessel represented in this figure, standing upon the shelf in the pneumatic cistern, and filled with oxygen gas. Its purity is tested by introducing into the vessel a lighted taper; if it burn with increased brilliancy, it is pure, oxygen gas. A piece of fine iron-wire having been prepared into a coil, by winding around a larger wire, has at the end a piece of thread covered with sulphur. Having been inflamed by holding it for an in-

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What may be done with oxygen gas after obtaining it?
What is the first property of oxygen which is mentioned?
What experiments hows that oxygen is the supporter of combustion?

stant in the flame of a lamp, the coil of wire is then plunged into the vessel of oxygen ;—a beautiful and splendid appearance is now presented by the burning of the metal, which throws off sparks glittering like the most brilliant stars. If there were sufficient oxygen, the metal would continue to burn, until the whole wire was consumed. The product of this combustion is a little ball of melted iron, which will fall into the water at the bottom of the vessel.

Explanation.—Oxygen, being a powerful supporter of combustion, is capable of igniting metals, surrounded by it, with some increase of temperature at first. The thread, dipped in sulphur and inflamed, gave the first impulse to combustion, and the oxygen gas supported, and gave it the force and power which this experiment manifests. In this process, the caloric which existed in combination with oxygen gas, is pressed out by the union of oxygen with the iron wire. The little ball of iron is an *oxide of iron*, and on being weighed, is found to be heavier than the wire before it was burned; this shows that it has gained something; and since there was only iron and oxygen gas, in the vessel, besides the caloric necessary to hold oxygen in the state of a gas, and this has been seen to come out from its latent to a free state; we must, since the oxygen has disappeared, conclude that it united with the iron, which conclusion is confirmed by the fact, that the iron has actually acquired something which adds to its weight.

We see from this experiment, that if the air were pure oxygen, every thing would be consumed. No sooner would a fire be kindled in an iron stove, than the stove itself would begin to burn. The brass tube of the bellows with which we blow the fire, would itself burst into

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How do you explain the appearances exhibited in this experiment?

What consequences would ensue if the air were pure oxygen?

an intense blaze, and the blacksmith, in attempting to pursue his labours, would see his hammer and anvil kindling into a flame.

But the Author of nature has in this, as in all his works wisely and kindly ordered his works, so that the life and comfort of his creatures are preserved and promoted. He has therefore given to the air that proportion of oxygen which promotes the combustion of wood, oil and coal sufficiently for all the purposes of human life; less oxygen would be insufficient to afford us the necessary fire and light; more oxgyen would render combustion dangerous and destructive.

The oxygen of the air is diluted or tempered with another gas, called *nitrogen*, which we shall soon examine.

It is important that you should consider attentively what takes place in burning or combustion. You have, in the burning of metal, understood that though there is a change of state in the two substances, oxygen gas and iron, yet neither of them are destroyed or lost. This is the case with every thing that burns; nothing is destroyed, but substances in burning change their state or condition. Some portion passes off in smoke or vapour, another remains in the form of coal, ashes or soot.

Philosophers say, and the assertion appears to be proved by all the experiments which have yet been made upon material substances, that no portion of matter has ever been destroyed. Thus we find that not even in burning, which seems the most destructive of all processes, is any particle lost, who then would dare to say, since God thus saves every material atom that he has created, that he will annihilate the noblest of his works, the human soul?

What is remarked of the adaptation of things by the Creator for the good of his creatures?

By what is the oxygen of the air diluted?

Are substances destroyed by burning?

What argument for the immortality of the soul, seems to be afforded by the fact here stated?

Combustion, or Oxidation.

The union of any substance with oxygen is considered as a kind of combustion or burning. Iron *rust* is an instance of *slow* combustion; this is an *oxide of iron.* Any iron vessel or utensil which stands long exposed to the weather will become rusted. Iron has such an affinity for oxygen, that it attracts it from the air, and from the moisture which is in the air; if the vessel is left with a little water in it, the oxygen from the water hastens the process of oxidation.

You will recollect that a *burnt* and an *oxidated substance* mean the same thing. All bodies which will unite with oxygen are therefore called *combustible;* the metals, gases, and indeed all the simple elements, unite with oxygen in a greater or less degree.

There are various degrees of oxidation, the lowest is called an *oxide*, the highest an *acid.* Some substances unite with oxygen in only one proportion, others in four. The lowest proportion in which oxygen unites with any substance is 8; therefore this is considered the representative number of oxygen; a second proportion of oxygen would be 16, a third 24, and so on, each being some multiple of 8.

Oxygen important to Animal Life.

2. A second important property of oxygen is, it *supports respiration*, or *breathing.*

A little girl caught a beautiful humming bird, and to secure it till she could procure a cage, put it under a large bowl. In a little time, going to look at her bird, she found to her sorrow that it was dead. Had

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What is iron-rust an instance of, and why is it that this substance forms so readily upon iron?

What substances are called combustible?

What is said of different degrees of oxidation?

What is the second important property of oxygen, and what anecdote is related in order to illustrate this?

she understood Chemistry, she would have known that the bird, small as it was, would soon consume in breathing all the oxygen contained in a bowl full of air, and then nothing would be left but *nitrogen*, which cannot support life, and another gas thrown off in breathing, viz. *carbonic acid*, which is destructive to life.

If you put a lighted taper or candle into a glass vessel of common air, it will at first burn as usual, but soon grow dim, and at length be wholly extinguished. This is because all the oxygen of the air is consumed. Thus, in a tight, crowded room, we perceive the lights to become dim, and persons often faint, requiring to be carried where they can have fresh air. Both the burning of the lights and the breathing of the people, exhaust the air of oxygen, and although there is no ordinary room but admits some air, still, under such circumstances, the main body of the air must be unwholesome. No animal can live in air that will not support combustion. But beside the want of oxygen, there are other circumstances which render the air in certain situations destructive to life and combustion. We shall consider this more particularly when we treat of carbonic acid gas.

Oxygen the great Acidifying principle.

3. A third important property of oxygen is, that *it produces acids.* It was long considered as the only *maker of acids* which exists, and is now supposed to be of much greater importance in this respect than any other substance.

What may we infer respecting the quality of air, when a candle will not burn freely in it, and why does the air in a crowded room and with many lights, become bad?

What is a third important property of oxygen?

The figure represents the burning of a substance called *phosphorus* in oxygen gas. The phosphorus is contained in the bent spoon, which is introduced into the jar of oxygen gas; on inflaming the phosphorus, it burns with great brilliancy. A white, flaky substance, which soon appears on the sides of the vessel, is then rinsed off into water. On tasting the liquid it is found to be sour; it will also redden blue vegetable colours, which is another proof of its acid property.

Explanation.—The jar contained only water, oxygen gas and phosphorus; nothing now remains of these three substances but the sour liquid, therefore we infer that the union of oxygen with the phosphorus has made it acid; this is called *phosphoric acid.*

Cider becomes vinegar, in consequence of uniting with a portion of the oxygen of the air. It is, therefore, necessary, to leave the barrel which contains the cider unstopped, and exposed to the air. Light has also an influence in promoting the union of oxygen with other substances. The barrel should be but partly filled, in order that a greater portion of the liquid may have access to the air at once.

Discovery of Oxygen.

This gas was discovered about the year 1774, by Dr. Priestly, an English Chemist, though two Chemists, Scheele of Sweeden, and Lavoisier of France, are sup-

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What does the figure represent?
How do you explain this experiment?
What is the cause of cider becoming vinegar?
When and by whom was oxygen discovered?

posed to have made a similar discovery about the same time. Dr. Priestly observed, that by heating certain metals, a kind of air was obtained, much purer than the atmosphere, and in which combustible substances burnt with great brilliancy; such was the simple manner in which this wonderful gas was first introduced to the notice of the world. Since that period, the whole science of Chemistry has changed its character, and all has seemed to become subservient to this great agent. 'Oxygen,' says a celebrated chemist, 'may be considered as the central point around which Chemistry revolves.' We should not fail to inform you that oxygen gas is thrown off by vegetables, in a proportion, about as great, as that consumed by animals; thus the one part of creation is made to depend on the other.

CHAPTER X.

Nitrogen. Atmosphere. Nitric Acid. Law of Definite proportions. Nitrous Acid. Nitric Oxide. Nitrous Oxide.

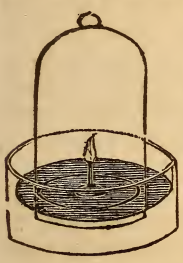
We are now to examine a substance which, though resembling oxygen in being a gas, without either colour or odour, is yet very different in its essential properties.

Nitrogen is so called because it exists in *nitre;* it was at first called *azote* from the Greek *a*, to deprive of, and *zoe*, life, because an animal soon dies when surrounded by this gas. The French still retain the name azote.

What is said of the substance now to be considered?
From whence are the terms nitrogen and azote derived?

Nitrogen composes four fifths of the common air; that is, air consists of four parts of nitrogen to one of oxygen, when reckoned according to the space they occupy; thus four tumblers of the one with one tumbler of the other, would make a compound, resembling the atmospheric air. In estimating by *weight*, the proportions are different, for nitrogen is a little lighter than the air, and oxygen a little heavier; thus *two proportions* of *nitrogen to one of oxygen*, when reckoned in weight, make common air. The proportional number of nitrogen is 14; two proportions are 28;—the proportion of oxygen is 8, therefore these two gases in the atmosphere are as 28 united to 8.

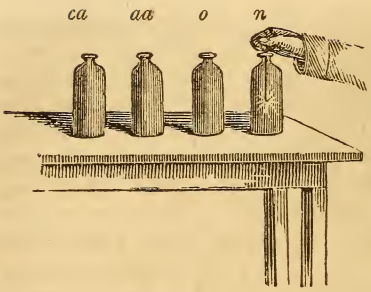
Nitrogen gas may be obtained in a very simple manner. Place a bell glass over a vessel containing a little water, and introduce a lighted taper under it, as you see in the figure. When the taper goes out, you have an evidence that the oxygen of the air has been consumed; the nitrogen which does not unite to the burning body is left free. As oxygen is absorbed, water rises in the bell glass to fill its place. By this method of obtaining nitrogen, the gas is not left entirely pure, since some vapours from the burning taper have mingled with it; but it is sufficiently pure to exhibit the most striking properties of this substance.



Nitrogen destroys Combustion.

A very elegant and striking experiment may be made, to prove that nitrogen destroys combustion, that oxygen supports it, and that a mixture of these two gases in the proportion of four parts of nitrogen to one of oxygen, makes a compound resembling atmospheric air.

What is air composed of?
How may nitrogen gas be obtained?
What may be proved by an experiment?



Experiment.—Four large vials are represented in the cut, which you are to suppose filled as follows; the first *n*, with nitrogen, the second *o*, with oxygen, the third *aa*, with a mixture of the two, forming artificial air, and the fourth *ca*, with common air, or as we say (though not scientifically) empty. A little wax taper suspended by a wire, and burning brightly, is first let down into the vial of nitrogen; here it will be immediately extinguished, but while the wick yet remains at a red heat, the taper is plunged into the second vial containing oxygen, here it is relighted and burns brilliantly; the taper is then let down into the third vial containing the artificial air, where it burns less vividly than in the oxygen, and in the fourth, which is filled with common air, it burns exactly in the same manner as in the third.

Explanation.—Nitrogen affording no aid to the burning process, the flame of the taper expired—oxygen by its energy rekindled it; and the burning of the taper in the two last vials proved that the mixture of nitrogen and oxygen, in the proportions of four to one, formed air resembling that of the atmosphere.

Although nitrogen does not support combustion, it does not act as a positive agent, but destroys the flame by preventing the approach of oxygen; in the same manner a burning taper, wholly immersed in oil would be extinguished.

Nitrogen destroys animal life; but as in the case of

What does figure the represent?
Explain the experiment.
Does nitrogen by its own power destroy flame?

combustion, it is not an active agent; an animal confined in it, dies for want of oxygen.

It possesses the *positive electricity*, as when subjected to the action of the Galvanic circle it is attracted to the negative pole.

It is contained in all *animal substances*, but in few vegetables: the cruciform plants, such as cabbage, turnip, &c. contain some nitrogen.

Except when combined with other substances, nitrogen is not active in its properties, but it forms many important compounds.

It was discovered about the same time as oxygen; that is about the year 1774, or two years before the Declaration of American Independence.

ATMOSPHERE.

We have examined separately two *elements* or two letters of the alphabet of Chemistry: we have found that these combined, form the atmosphere or air.

This surrounds the globe to an extent not exactly known, but supposed to be about forty-five miles in height.

The air was long considered as a simple body, but some chemists had begun to suspect its compound nature, when Lavoisier proved by a course of experiments that it was composed of two gases which possessed very different properties; his discoveries were of great use to succeeding chemists in enabling them to ascertain the nature of these gases, and the proportions in which they naturally exist.

How does nitrogen affect animals?
How is nitrogen affected by the galvanic circle?
Is nitrogen contained in animals and vegetables?
Is nitrogen important when uncombined with other substances?
When was it discovered?
Of how many elements is the air composed?
What is the height of the air?
What is said of Lavoisier's experiments upon the air?

Air is now known to consist of 21 parts of oxygen gas, and 79 of nitrogen in 100 parts; it also contains aqueous vapour and a small portion of carbonic acid, probably one part in a thousand. Though other gases may arise from the earth and mingle with the air, neither they nor carbonic acid are considered as essential parts of it.

Carbonic acid gas is diffused into the atmosphere in various ways, chiefly by the burning of vegetable substances and the breathing of animals. The air would by these means soon become impure, were it not that vegetables, needing carbon to promote their growth, take it up from oxygen with which it is combined in carbonic acid gas, and which being thus disengaged, returns back to purify the air. In countries where a low temperature during a part of the year, as in New England, prevents the active growth of vegetation, the winds which agitate the atmosphere, and the mosses and evergreen maintain an equilibrium in the proportion of oxygen in the atmosphere.

Atmospheric air has neither colour nor smell; in these respects it resembles oxygen and nitrogen gas; its weight or specific gravity is estimated as 1, the weight of all other æriform fluids being settled by a comparison with it; thus the specific gravity of oxygen is 1.11, or a fraction more than the weight of air, while that of nitrogen is .9722, or less than a unit.

It is not entirely settled among chemists, whether the air is merely a *mixture* of the two gases, or a *chemical* combination. If it were only a mixture, we should expect the heaviest portion, oxygen, would settle below the other part; but we do. not find in portions of air

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What is air now known to consist of, and what substances mingle with it, that are not considered as essential ingredients?

What prevents carbonic acid from increasing so much as to destroy the purity of the air?

What is said of the colour, smell, and weight of the air?

Is air a *mixture*, or a *chemical combination?*

standing in a vessel undisturbed, that this separation does take place—and yet the experiment of making artificial air, by simply mixing the two gases, would tend to prove that it is not a chemical combination, or if so, that the affinity is not strong between the gases, since the union takes place without any agitation.

The following are some of the most important properties of air: it is a *bad conductor of electricity and heat;* it supports *combustion;* by parting with oxygen it causes *acidity* in many liquids; it *oxidizes metals;* it is *necessary* to *breathing*, on account of the oxygen which it contains; it is heaviest near the earth; it is coldest in the higher regions; it may be compressed by being subjected to a heavy weight; and it may be dilated by heat.

When air is decomposed, it is always the oxygen which unites with other bodies; no substance is known which will absorb nitrogen from the air.

We shall now observe some other combinations of the two gases which form the atmosphere; but instead of a mild substance like the pure air, we shall here find one of the most destructive and corroding of all the acids.

NITRIC ACID.

Nitric acid is so called because it was first obtained from the nitrate of potash (saltpetre); it was at first called the *acid water of nitre*, afterwards *spirits of nitre*, and *aqua fortis*;* it was called nitric acid in 1782 by the French chemists.

* *Aqua fortis* means strong water, being from the Latin *aqua*, water, and *fortis*, strong; this is the common name for nitric acid.

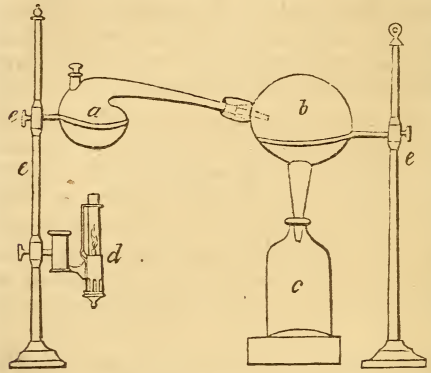
Mention some of the most important properties of air.

In order to decompose air, which of its elements unites with other substances?

Are all the combinations of oxygen and nitrogen mild like the air?

Why is nitric acid thus named?

Experiment.—This acid may be obtained by the following method; three parts of pounded saltpetre, or *nitrate of potash*, are put into a tubulated retort, such as you see in the figure at *a*; upon this is poured sufficient sulphuric acid to wet it; on applying heat to the retort from the lamp at *d*, the nitric acid gas will begin to pass over into the receiver *b*, from whence it will pass into the bottle *c*, where it will be absorbed by water, a small portion of which had been put into the bottle for that purpose. Upon examining the water it will be found to be weak nitric acid, or aqua fortis.



Explanation.—The nitrate of potash is composed of nitric acid and potash; the latter having a stronger affinity for sulphuric than for nitric acid, unites with it, and the nitric acid being excluded, passes off in gas. The use of the tubulated retort is to let out the common air when the gas begins to ascend, and also by the little tube, the sulphuric acid is introduced after the apparatus is fitted in the manner represented by the cut. A glass stopper closes the aperture when necessary; at *e e* is represented a lamp-furnace and a stand, which are very important parts of a chemical apparatus.

Nitric acid, when combined with water, is called *hydro-nitric acid*, from the Greek *udor*, water, when in a

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What experiment is figure the designed to illustrate?
Explain this process.
What are the different names for nitric acid when with or without water?

dry state, or without water, it is called *anhydrous* nitric acid, from a Greek preposition, signifying without, added to the word denoting water; but such is the affinity of this acid for water, that it is seldom found entirely free from it.

Its *specific gravity*, or weight compared with water, is 1.5, that is, one and five tenths, which is equal to one and a half.

Nitric acid resembles water in having neither colour nor smell, but it is extremely caustic and corrosive; it acts strongly upon animal and vegetable substances. A drop of it upon the flesh causes a burning sensation, and produces an ulcer as if fire had touched the spot. It is actually a *burn*, since the effects are produced by the oxygen, which, leaving the acid, unites to the flesh, or oxidates it; and *oxidation*, you have learned, means the same thing as burning, although there are very low degrees of it, which do not produce the effects commonly ascribed to burning.

It is because nitric acid readily parts with oxygen, that it produces the effects we have just described. Most combustible substances decompose nitric acid by attracting its oxygen; the quantity of oxygen absorbed, varies according to the affinity of substances for this gas.

ILLUSTRATION OF THE LAW OF DEFINITE PROPORTIONS, OR ATOMS.

No part of the study of Chemistry illustrates more fully, the law of *definite proportions*, than that of nitrogen, considered in reference to its various combinations with oxygen. This law we have already mentioned in several instances. In treating of affinity, we found that sulphuric acid united with soda to form the sulphate of

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What is the specific gravity of this acid?
What are some of the properties of nitric acid?
Does nitric acid part with oxygen readily?
What law is illustrated by the combinations of nitrogen and oxygen?

soda; but when the two substances had combined exactly in the proportion to form that salt, their union would proceed no farther.

Nitrogen and oxygen unite in several proportions. You may understand this the better if we use the term *atoms*, which some chemists adopt. For instance, 14 being the lowest proportion, in weight, in which nitrogen unites with any substance, this is considered as its *ultimate atom*, or the lowest division of it which can be made. The lowest proportion in which oxygen unites with any substance, is 8, therefore these are considered as the weight of their respective atoms. That of another gas, hydrogen, one atom of which with 8 of oxygen form water, is represented by 1. These atoms may be represented by signs thus:

weight.

1—⊙ atom of Hydrogen,
14—Φ " Nitrogen,
8—*O* " Oxygen.

Water, which is compounded of an atom of oxygen and one of hydrogen, may be either represented by the sum of 1 and 8, which is 9, or by the signs, ⊙ *hyd. O ox.* Air, which is composed of one atom of oxygen and two of nitrogen, may be either represented by the sum of 8 and 28 which is 36, or by the signs, *O ox.* ΦΦ *nit.*

Besides the union of nitrogen with oxygen, forming atmospheric air, these two gases unite to form five different compounds; viz.:

Nitrous oxide, one atom	Nitrogen 14	to one oxygen	8
Nitric oxide "	Φ = 14	*OO*	= 16
Hypo*-nitrous acid "	Φ = 14	*OOO*	= 24
Nitrous acid "	Φ = 14	*OOOO*	= 32
Nitric acid "	Φ = 14	*OOOOO*	= 40

* *Hypo* is a Greek preposition signifying *under;* the term *hypo-nitrous acid* denotes that it is less acid than *nitrous acid.*

What numbers express the ultimate atoms of nitrogen, oxygen, and hydrogen, and by what signs are they represented?

How may water and air be represented?

What other compounds besides air are formed by the union of nitrogen with oxygen?

All these combinations will be seen to be formed either with the atom 8, or some multiple of it, as twice, three times, four times, and five times 8. The number which represents the compound is the sum of all the atoms; thus the representative number of nitric acid is 54, it being composed of oxygen 40 and nitrogen 14.

NITROUS ACID.

Nitrous acid has been long known in Chemistry; indeed the chemists of the last century called all the gases formed by a union of nitrogen and oxygen, by the general name of nitrous acid gas. But as we have already observed, there are now known to be several distinct gaseous compounds of this family.

We have found that nitric acid exists in a liquid state. When this substance loses one portion of its oxygen, it exhibits red fumes or vapours, and is changed to nitrous acid gas. Nitrous acid may also be obtained by heating in a small retort, the nitrate of lead. It is remarkable for its colour, which at a low temperature is a bright orange. When water absorbs this gas, it first appears green, then blue, and at length orange colour. The liquid when tested, is found to be acid.

HYPO-NITROUS ACID.

Hypo-nitrous acid, which means a substance containing less oxygen than nitrous acid, though named and described by chemists, seems to be but little understood by them; indeed, they seem to be scarcely certain that they have ever obtained it. Since this is the fact, we will not puzzle the beginner with attempting to explain at what exact point, when uniting with more oxygen to form nitrous acid, the nitrous acid passes into the hypo-nitrous state.

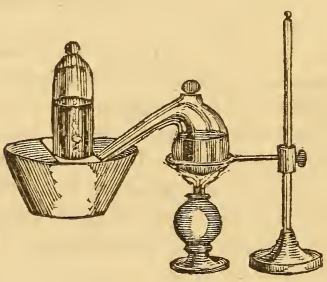
Why is the representative number of nitric acid 54?
Has nitrous acid been long known?
How may nitrous acid be obtained?
For what is this gas remarkable?
What is said of hypo-nitrous acid?

NITRIC OXIDE.

Nitric oxide is also called *nitrous gas*, and the *deutoxide of nitrogen*. It is lower as respects the proportion of oxygen it contains, than the hypo-nitrous acid, and higher than the nitrous oxide, which being the lowest combination of oxygen with nitrogen, is called a *protoxide*.

Nitric oxide may be obtained from nitric acid, by the following process.

Experiment.—Put some small bits of copper, or copper filings into a retort, as seen in the figure, and pour upon them some nitric acid. As soon as the heat of the lamp passes into the retort, a violent action commences, and a red looking gas begins to pass over; this is *nitrous* acid, which having a great affinity for water, unites with that in the tub; then appears a colourless gas, which does not unite with the water, but passes through it into the bell glass in little bubbles, the water in the bell glass gradually sinks as it fills with *nitric oxide gas*.



Explanation.—Nitric acid contains five atoms or proportions of oxygen; three of these unite with the copper, and form an oxide of copper; two atoms of oxygen then being left with the nitrogen, form the gas called nitric oxide, which passes off through the tube of the retort into the receiver.

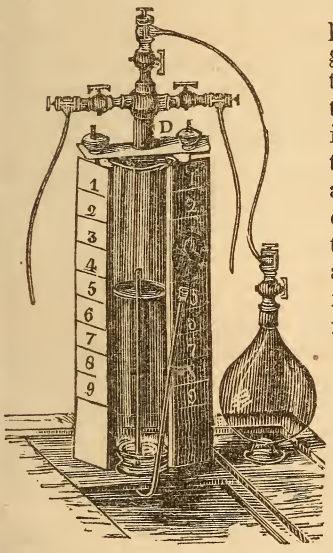
By what different names is nitric oxide known?

Describe the manner of obtaining nitric oxide or the deutoxide of nitrogen.

How is the experiment for obtaining nitric oxide explained?

But in the retort was a portion of atmospheric air, which furnishing oxygen, changed the nitric oxide into the red or orange coloured gas, called nitrous acid, which united with the water of the receiver. As soon as all this was taken up, the pure nitric oxide passed over.

Nitric oxide is of use among chemists to determine the proportion of oxygen in the air; for so great is its affinity for this gas that when mingled with common air, it attracts all the oxygen, and becomes the red nitrous acid, leaving nitrogen free. The nitrous acid which is formed, may be wholly absorbed by water.



In this figure you are presented with a very ingenious instrument, contrived by Dr. Hare for the analysis of atmospheric air, by means of nitric oxide. It is called a *volumescope*. It consists of a hollow glass cylinder, thirty inches high, and four and a half in diameter; it is placed over the pneumatic cistern. On each side of the cylinder, there are strips of wood on which are marked degrees. You perceive three tubes; these are of lead, and made flexible, so that they can be bent as may be necessary; the entrance to each of these tubes may be closed by the turning of the stop-cocks which appear near the places of their connexion

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What useful application do chemists make of nitric oxide? Explain the use of the volumescope.

with the instrument. To one of these tubes is connected a pear-shaped bottle which Dr. Hare calls a *volumeter* (a measurer of volumes, or of equal quantities.) This bottle holds just as much air or gas as three degrees of the glass cylinder. Now supposing part of the air to be exhausted from the cylinder by means of an air pump, to which one of the tubes is made to communicate; the water then rises up to fill the vacuum. The volumeter being filled with nitric oxide, and a communication opened by turning the stop-cocks, gas ascends into the cylinder. The orange red fumes of nitrous acid then appear. By means of an India rubber bag and tube, jets of water are thrown up into this gas, which is soon wholly absorbed by the water. The number of degrees which the water rises, shows the quantity of gas which has been taken up from the air, and as oxygen only unites with the nitric oxide, forming, by its union, the orange, fuming gas, called nitrous acid, the quantity of oxygen which the air contained, is thereby ascertained. That is, the whole portion of air having at first been measured, by observing how much nitrogen remains, we are able to tell the quantity of oxygen which has been absorbed.*

NITROUS OXIDE.

You know that the termination in *ous* denotes a lower proportion of oxygen than that in *ic*. Nitrous oxide, therefore, as the name would denote, has less oxygen in combination with it than nitric oxide, which we have just examined. Nitrous oxide is sometimes called the protoxide of nitrogen, while nitric oxide is the deutoxide.

* This somewhat complicated instrument may not be understood by the young pupil; though its object may be clearly comprehended. As Dr. Hare had kindly forwarded to the author some papers containing his recent discoveries and improvements, she was anxious to show to the beginner, some of the curious apparatus by which he so happily illustrates some of the most difficult subjects in Chemistry.

What does the name *nitrous* oxide denote?

Nitrous oxide may be obtained from nitric oxide, by the action of substances which will abstract one atom of its oxygen.

Nitrous oxide is more like the common air than any of the other combinations of nitrogen with oxygen, since it may be breathed with more safety. It was quite fashionable, a few years ago for those who attended chemical lectures, to prove the nature of this gas by inhaling it into the lungs. It was at first thought to be harmless; but at length cases occurred in which it produced faintness and distress, and threatened serious injury. The effects of breathing nitrous oxide were in many cases singular, and often highly ludicrous. It was perfectly intoxicating to many. The most serious persons, under its influence would become gay, and vent their feelings by immoderate laughter, capering about the room, or opening their mouths without being able to close them, although sensible of making a most ridiculous appearance. Fun-loving urchins, and frolicsome youths, after breathing nitrous oxide, would sometimes suddenly assume the most laughable and incongruous gravity of countenance and demeanour, gazing around without the power to smile at their own appearance. Sir Humphrey Davy, the first who attempted inhaling it, breathed four quarts of the gas. Some who repeated the experiment after him, declared it must be 'the very atmosphere of heaven.'

It is now acknowledged by chemists, that there must danger in inhaling nitrous oxide, from the difficulty of obtaining it entirely free from some portion of nitric oxide, which is suffocating and destructive of life.

We perceive, in learning the nature of nitrogen and oxygen, that the proportions which the Almighty has

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How may it be obtained?

What is said of breathing nitrous oxide?

What renders it dangerous to inhale nitrous oxide?

What fact do we perceive respecting the composition of the air, by learning the properties of oxygen and nitrogen?

established between these two gases in the atmosphere, are exactly such as the living beings who exist in it need. Less oxygen would not be sufficient to support respiration, more would quicken and stimulate the vital powers to a degree which would soon destroy them; or, as has been said, 'as a candle burns brighter in oxygen gas and is more quickly consumed, so in this gas, the flame of life would be more vivid, but sooner burnt out.'

We have now seen that with two elements or letters of the alphabet of Chemistry, several substances are formed, viz: air, nitrous oxide, nitric oxide, nitrous acid, and nitric acid.

Nitric acid forms with various substances, *nitrates*, and nitrous acid forms *nitrites*. There are many other important compounds formed with nitrogen, which we shall notice hereafter, when we have learned something about the other elements with which it unites.

CHAPTER XI.

Hydrogen. Its properties. Its agency in producing Earthquakes and Volcanoes. Water. The Compound Blowpipe.

We are now to examine a new element, hydrogen; the name of which is derived from the Greek *udor*, water, added to a word signifying to produce, because that in connexion with oxygen it forms water.

What substances have we found to be formed by two letters of the alphabet of Chemistry?

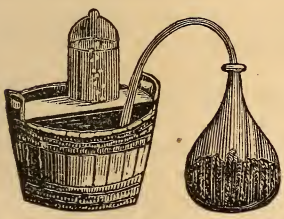
What are nitrates and nitrites?

What does the word hydrogen signify?

In studying the gases we are continually met by new and interesting facts; and the gas, now under consideration, furnishes its full proportion of beautiful experiments; —but we will first observe the manner in which it is obtained; this, like oxygen, must always be in a gaseous state, since such is the affinity of hydrogen for caloric, that it can never be solidified.

Mode of obtaining Hydrogen Gas.

Water being composed of hydrogen and oxygen, if the oxygen unites to a metal, the hydrogen will be liberated and pass off in the state of gas.



Experiment.—Some iron filings being put into a flask, and weak sulphuric acid poured upon them, a lively effervesence takes place; the hydrogen gas immediately begins to escape, and, by means of the tube which passes under the mouth of the bell glass, is collected through water. Nearly half the water, with which the bell glass was filled, has disappeared, the gas having risen and taken its place.

Explanation.—The oxygen of the water being strongly attracted by iron, leaves the hydrogen and unites with the metal; the hydrogen, which existed in a liquid state with oxygen, is no sooner disengaged, than it combines with sufficient caloric to become a gas. The manner in which sulphuric acid aids the process, is not satisfactorially explained by chemists. Professor Silliman says, 'it appears to me better to say that we do not understand

---

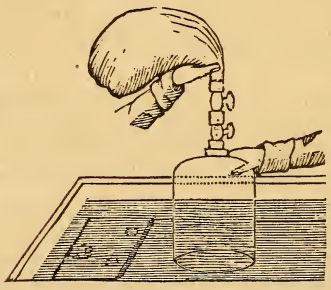
In what form is hydrogen always obtained?
How can hydrogen be obtained from water?
What does this figure represent?
What explanation may be given of the changes which take place in this experiment?

it, and to wait till we do, before we attempt to explain the fact.' The oxygen of the water uniting to the iron filings forms an *oxide of iron*;—the sulphuric acid is not decomposed, but unites with the newly formed oxide and forms a *sulphate of iron*, (copperas,) which when allowed to stand for a sufficient time, appears under the form of green crystals. No heat is applied in performing this experiment, but so much caloric is disengaged by the chemical combination of the sulphuric acid and water, as to heat the flask.

Iron heated to redness, decomposes the steam from boiling water, by uniting with the oxygen and setting the hydrogen free.

Properties of Hydrogen.

Having collected Hydrogen gas, we will proceed to an examination of its properties. 1. It is the *lightest* of all substances which have been weighed, that is, of all *ponderable* substances, being about 14 times lighter than atmospheric air, and 16 times lighter than oxygen.



Experiment.—The levity of hydrogen gas is very prettily exhibited by the following experiment. A bladder fitted for the purpose, and filled from a bottle of the gas in the manner here represented, is used to for the purpose of blowing bubbles in soap suds; these bubbles being shaken off the end

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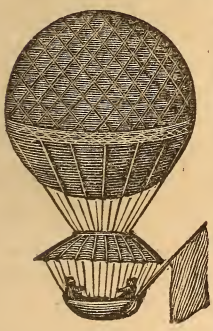
How does hot iron decompose steam?
What is the first property of hydrogen which is mentioned?
By what experiment is the lightness of hydrogen illustrated?

of the tobacco pipe, which is fitted to the mouth of the bladder, rise through the air, until stopped by the upper ceiling of the room.

Explanation.—The bubbles, being inflated with hydrogen gas, ascend because they are lighter than air. The figure shows a bubble just passing off from the pipe; if a lighted candle is held so that the flame comes in contact with the bubbles, they explode and burn.

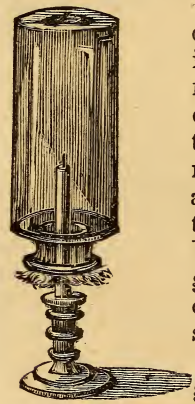
Balloons ascend on the same principle as these bubbles;—they are made of oiled silk, inflated with hydrogen gas. As a large quantity of the gas is needed for this purpose, barrels or other capacious vessels are used for containing the water which is to be decomposed, and the hydrogen is conducted into the balloon by means of long flexible tubes. The *æronaut*, (as the navigator of a balloon is called,) must experience new and sublime emotions as the car in which he sits, rises aloft into those regions of the air which no human being



What causes the bubbles made with hydrogen to rise?
What is said of the ascension of balloons?

has before penetrated. The heavens above him appear as if studded with silver upon a ground of black. The presumption of man might indeed lead him to attempt to make these aerial voyages to a much greater extent than has yet been done, he might even hope to be able to visit distant planets even in his earthly body; but God has placed an eternal barrier in his physical constitution, which can endure the rarity and cold of the atmosphere but a few miles above the earth, and these constantly increase as we ascend.

2. Hydrogen *is highly combustible; though it does not support combustion.*



A lighted candle placed under a jar of this gas, and with its flame immersed in it, is extinguished as you see in the figure. This is because there is no oxygen to support combustion; for in this process, two things are always necessary, a combustible substance, and a supporter of combustion. Here then we have one, but not the other. When the candle is immersed in oxygen gas, it burns, because it is itself combustible, and it is surrounded by a supporter of combustion.

The following figure shows hydrogen itself burning; the bottle contains

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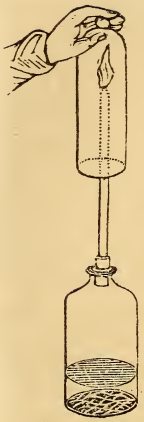
What is a second property of hydrogen?
What does the figure represent?

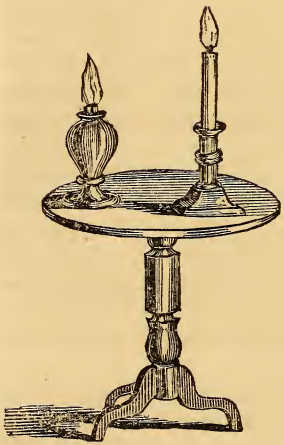
water, iron filings and weak sulphuric acid, the water immediately begins to be decomposed and the hydrogen to rise into the tube, which is fitted to the mouth of the bottle. On applying a lighted candle to the tube, the gas is inflamed and burns as you see.* This is called the philosophic candle. To the ignorant, it might well afford matter for astonishment to see a bottle of water burning, and its pale, unearthly looking flame, might confirm their superstitious belief that this phenomenon must be the effect of magic. But you can understand that the combustible substance, hydrogen, being inflamed by the candle, and furnished with oxygen from the surrounding air, burns as oil would in the same situation. The figure on page 118, shows a flame at the mouth of the bottle; this is the hydrogen gas which was set on fire by the flame of the candle, although this flame was itself extinguished on being wholly immersed in the gas.

* The young ladies of the Seminary of Troy N. Y. who are in the habit of performing chemical experiments in their daily exercises and at the public examinations, have by means of a suitable apparatus, exhibited some splendid experiments, to illustrate the burning of hydrogen and carburetted hydrogen.

How does it appear that hydrogen is combustible?



But what do you think is the product of this combustion of hydrogen? You will perhaps be surprised to learn that it is water. If you hold a bell glass over the flame of burning hydrogen, you may see a moisture upon its sides, occasioned by the union of the hydrogen with the oxygen of the air.



This figure presents you with another instance of the burning of hydrogen. You say—'we see nothing here but a common looking lamp, and candle.' The burning of lamps and candles is, however, one form of the combustion of hydrogen. This may be proved by holding a tube for some time over the flame; moisture will collect upon the sides of the tube. This moisture is formed by the union of oxygen and hydrogen. The oil and tallow furnish hydrogen; it is this which renders them so combustible; they contain also another combustible substance, *carbon;* but it is the hydrogen,

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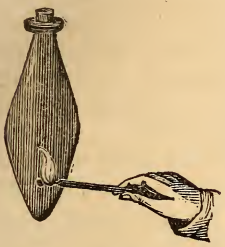
What is produced by the burning of hydrogen?
What causes the flame of lamps and candles?

principally, which causes the flame. The air furnishes the necessary oxygen.



3. Hydrogen when mixed with oxygen or atmospheric air, on being inflamed, *explodes* like gun powder. The firing of the hydrogen gun, in the lecture room of the chemist, often causes, both terror and amusement. A vessel of tin is filled with a mixture of one part hydrogen to two of air; a cork is then put into the open end. On applying a lighted taper to a small aperture, the gas inflames, and expands so much as to drive out the cork with great force, accompanied by a loud report.

From the explosive nature of hydrogen, it is thought that this gas is concerned in producing earthquakes. In the bowels of the earth are vast quantities of iron; water also exists in an equal proportion, filling chasms and fissures in the rocks. You have seen that when water comes in contact with iron, it yields its oxygen to the metal, and the hydrogen becomes a gas. You have also seen that when this gas is mixed with atmospheric air, if it comes in contact with a burning substance, an explosion takes place. Thus we may imagine that in the vast caverns which exist in the earth, hydrogen mingling with the air meets with something which inflames it; in the explosion which follows, the ground is thrown up, and in some cases whole cities are buried up in the chasms thus made.

4. Hydrogen gas cannot be breathed by animals; like nitrogen, however, it destroys life rather by excluding oxygen than because it possesses any noxious quality. By

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What is the third property of hydrogen?

What reasons are there for supposing that hydrogen may be concerned in producing earthquakes?

What is a fourth property of hydrogen gas?

a mixture of hydrogen and oxygen, an atmosphere might have been formed that would have supported life. But such a mixture we have seen is explosive, and would have been destructive to the foundations of the earth itself. We see, therefore, that He who formed and tempered these elements, knows best how to mingle and proportion them, that they may all perform a part in sustaining, instead of destroying his other works.

Hydrogen gas exists in almost every compound substance; making a part in most fluids, as water, and every thing which contains water, and in all animal and vegetable substances. In minerals, especially coal, it exists in abundance. The wood which you see burn, owes its flame in part, to hydrogen, usually, however, combined with carbon, a substance yet unknown to you. The pale flame of wood is the hydrogen; it is most abundant in green wood, while carbon is more plentiful in dry wood, and affords a richer and a deeper flame. The sulphur which exists in coal often gives it a bluish flame. Oil and tallow, as we have remarked, contain a great portion of hydrogen, which causes their combustible nature.

Water, or Hydrogen and Oxygen united.

Water is composed of 2 parts of hydrogen and 1 of oxygen; that is when reckoned by bulk;—in weight, 1 part of hydrogen, and 8 parts of oxygen constitute water. This you can as easily understand, as that a quantity of feathers, occupying double the space of the same quantity of wool, might yet weigh but 1 pound, while the wool weighed 8 pounds.* The weight of the two elements, hydrogen 1, and oxygen 8, makes 9, which number represents water. It is important that you should recollect

* It is not important that the relative specific gravity of wool and feathers should be here given correctly, but the case is merely stated for illustration.

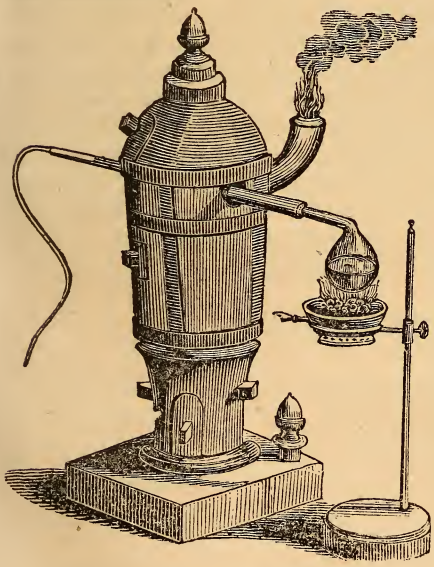
What is said of the difference of hydrogen?
What are the proportions of oxygen and hydrogen in water?

that the combining weight of hydrogen is 1, while that of oxygen is 8; this circumstance having given rise to what is called the theory of atoms, respecting which, we have made some remarks in the chapter which treated of nitrogen and its compounds.

The nature of water may be proved in two ways, *analysis* or a separation into the two elements, oxygen and hydrogen; and *synthesis* by which these two gases are combined and form water.

Analysis of Water.

When water in the state of steam is made to pass over heated iron, the metal absorbs the oxygen, and hydrogen gas escapes; the iron will be found to have gained in weight 8 grains of oxygen for each grain of hydrogen that is obtained.

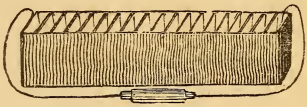


This figure shows an apparatus by which steam is decomposed by passing over hot iron. The iron tube to which the retort is cemented, is a gun-barrel; to the opposite end of which is fitted a flexible, leaden tube, for the purpose of conducting off the hydrogen gas that is to be obtained. Within the gun-barrel, is introduced a quantity of small bits of iron, and

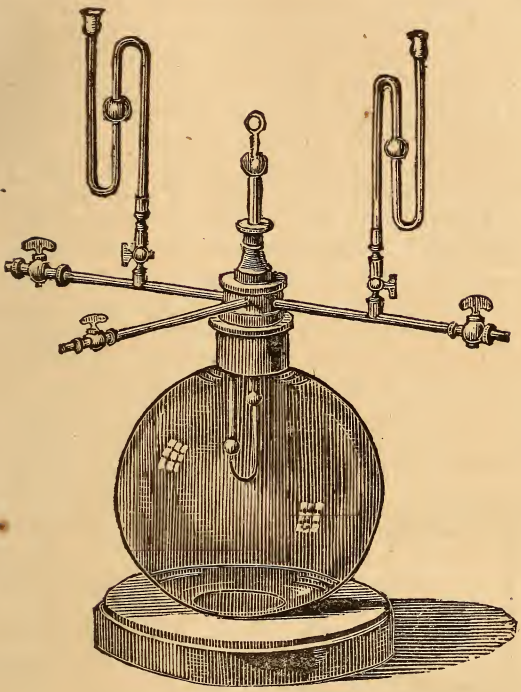
How may the nature of water be proved?
How may steam be decomposed?
Explain the figure.

the glass retort is partly filled with water. A quantity of charcoal within the furnace being ignited, soon heats the gun-barrel to a red and then to a white heat. In the mean time a chaffing dish of burning coals is placed under the retort; the water soon boils, is changed to steam, which passes through the gun-barrel and parts with its oxygen to the metal, while the hydrogen escapes through the leaden tube and may be collected.

When water is subjected to the action of the galvanic circle, it will be decomposed, hydrogen will appear at the negative pole, and oxygen at the positive pole. The figure shows you how this experiment may be performed. A glass tube, *a*, is filled with water, and corked at both ends; the two wires of the galvanic circle are then put through the corks. The water being acted upon by galvanic electricity, its elements separate, and hydrogen is attracted to the negative pole, and oxygen to the positive. You must now reflect a moment, whether this is because the gases have the same electricity as the poles to which they go, or whether it is because their electricities are opposite. Opposite electricities attract, while similar electricities repel one another.



What effect has galvanism upon water?



Forming of Water by synthesis.

We will now examine into the recomposition of water. 'This apparatus consists of a glass globe, with a neck cemented into a brass cap, from which three tubes pro-

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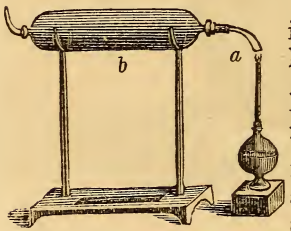
How may water be recomposed, or its elements united?

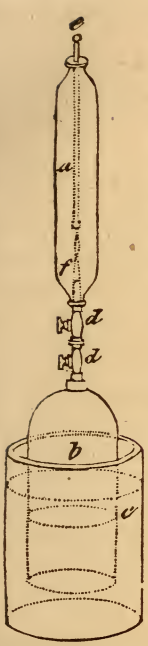
ceed, severally communicating with an air pump and reservoirs of oxygen and hydrogen. It has also an insulated wire fixed for producing the inflammation of a jet of hydrogen, by means of an electric spark. In order to put the apparatus into operation, the globe must be exhausted of air and then supplied with oxygen to a certain extent. In the next place, hydrogen is to be allowed to enter in a jet, which is to be inflamed by an electric spark. As the oxygen is consumed, more is to be admitted.'* The explanation of this figure being given in the words of a learned chemist, the beginner may not understand it all, but this you can comprehend; that the glass globe is first exhausted of atmospheric air, then filled with oxygen gas; and that a stream of burning hydrogen is made to pass into the globe. The two gases thus unite by combustion, and form *water*. The simple *mixture* of the gases does not form water, but it is necessary they should be united while burning.



Another apparatus for forming water by the burning of hydrogen is here represented. A current of burning hydrogen passes into the mouth of the tube *a*. The hydrogen in burning unites to the oxygen of the air, and the glass cylinder *b* soon appears lined with vapour which condenses in drops.

*Prof. Hare.

What other experiment illustrates the formation of water?



This figure shows hydrogen burning in an atmosphere of oxygen; *a* is a glass cylinder filled with pure oxygen; *b* is a receiver of hydrogen immersed in a vessel of water *c*. When the stop cocks *d d* are opened, the hydrogen rises through the capillary tube and on being inflamed by an electric spark, it burns with great force, and drops of water soon collect in the cylinder.

Water is called the *protoxide of hydrogen*, because it consists of hydrogen united to one portion of oxygen.

There is a *deutoxide* of hydrogen, sometimes called *oxygenated water*, but it is always the production of art; its properties are very different from those of water; it is corrosive to the skin and exhibits acid qualities. Here we see that one additional proportion of oxygen entirely changes the nature of water.

The union of oxygen and hydrogen may be thus shown:

Water, or the *protoxide of hydrogen*.

1 Hydrogen.	8 Oxygen.

Represented by 9.

Deutoxide of hydrogen.

1 Hydrogen.	8 Oxygen.
	8 Oxygen.

Represented by 17.

Water exists in nature in the form of a transparent, colourless, inodourous liquid, capable of dissolving a great variety of substances.

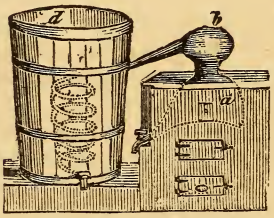
It becomes solid or ice at 32°, and assumes a gaseous

What is illustrated by the figure?
Why is water called the protoxide of hydrogen?
What is said of the deutoxide of hydrogen?
How does water exist in nature?

form at 212°, occupying a volume 1700 times greater than in the liquid form.

Freezing is the crystallization of water; its crystals are usually confused, but their form is that of hexagonal (six sided) prisms. Water is a bad conductor of electricity; it refracts light strongly.

Water is seldom found pure in nature; in order to obtain it in this state, it must be distilled. The figure shows the manner in which this is done. *a* Represents a boiler of water in a furnace; from *b*, the *head* of the still, the steam, which arises in boiling, passes into the *worm*, or spiral tube, where it is surrounded by cold water in the cask *d*, this condenses the steam, and drops of pure distilled water issue from the bottom of the tube. Distilled water is thought best for chemical experiments.



Water in a solid form constitutes immense glaciers upon the summits of high mountains, and exists in vast quantities in the polar regions. The clouds and vapours of the atmosphere are water in a gaseous form. When condensed by cold, it solidifies, and being then heavier than the air, it falls in the form of hail, snow, or rain.

Water was long considered as a simple element—it was not analyzed until the latter part of the eighteenth century.

We have now considered the subject of Hydrogen Gas. Its most important properties are its inflammable nature, and its lightness or specific levity. Its most important combination is water.

At what temperature is water solid, and at what does it become a vapour?

What is said of the crystallization of water?

How may water be obtained pure?

How extensively does water exist?

How long has water been known as a compound substance?

What are found to be the most important properties of hydrogen gas, and its most important combination?

Blow-Pipe.

We ought not to omit the mention of the *compound blow-pipe*, in which hydrogen in connexion with oxygen is made of great use in Chemistry. But first we will teach you the construction and use of the common *blow-pipe*, which you here see represented. It is merely a simple brass pipe having a bulb in the middle, tapering, and bent at the smaller end; it is used for impelling the flame of a candle or lamp upon any small substance, which the chemist or mineralogist wishes to heat. Stones and ores, are said to be *fusible* when they can be melted in this manner.

The compound blow-pipe or as it is sometimes called the Oxy-Hydrogen Blow-pipe is constructed in such a manner as to conduct through a small orifice the two mingled gases, oxygen and hydrogen, upon the substance to be melted; they are ignited as they pass out from the end of the pipe;—this flame is found to be very powerful. Dr. Hare of Philadelphia, was the inventor of this important instrument, and the discoverer of the intense heat produced by the united power of the two gases, employed. In no other way, except by means of galvanic agency, can such an intense heat be produced. The compound blow-pipe has melted every mineral that has yet been subjected to its operation except the diamond, this is so inflammable that it burns without first melting. All the metals not excepting platina, gold, and silver, have been melted and burned by this blow-pipe. Wire, made of iron or copper burns in its flame, as a piece of cotton in an ordinary flame; earths burn with great brilliancy; a bit of a China cup under its influence burns with too strong a light to be borne by the naked eye.

Describe the common blow-pipe.
What is said respecting the compound blow-pipe?

CHAPTER XII.

Sulphur. Combination of Sulphur with Oxygen. Selenium.

THE new letter in the alphabet of Chemistry, which you are now to learn is *Sulphur;* it differs from the elements we have examined in being found in a solid state, and existing in nature free from any combination. Sulphur was known in very ancient times, and has long been in common use as a medicinal article, while oxygen, nitrogen and hydrogen, are words familiar only to chemists, because it is only by chemical analysis that they can be obtained.

The word sulphur, is supposed to be composed of two Greek words, *sal* salt, and *pur* fire, so called from its great combustibility.

Pure sulphur has never been decomposed, it is therefore considered as a simple element; but such is its affinity for other substances that it is seldom found entirely pure with metals it forms *sulphurets* and *pyrites;* with oxygen it forms *sulphuric acid;* and this acid by its union with lime, soda, &c. forms *sulphates.*

Sulphur is abundant in volcanic countries; being combined with metals in the earth, it is separated from them by the heat of volcanoes, and becomes a vapour which rising from their craters falls again upon the surface of

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What new element are we now to consider, and why is its name more familiar than oxygen, nitrogen, and hydrogen?

From what is the word sulphur derived?

What are some of the compounds formed with sulphur?

In what situations is sulphur usually found, and in what substances is it contained?

the earth, forming a crust, and sometimes beautiful crystals. It exists in some plants, as cabbage and dock, and in some animal substances, especially eggs.

Sulphur is known in commerce in two states; the *flowers* or flower of sulphur and *brimstone*; the latter is in the form of *rolls*, made by pouring melted sulphur into small moulds. The sulphur of commerce is generally obtained by separating sulphur from some of its combinations.

The sulphuret of iron parts with its sulphur on being sufficiently heated.

Sulphur used for Bleaching

The colour and odour of this substance are familiar to all. When sulphur is thrown upon coals, it rises in vapour and uniting with the oxygen of the air forms sulphurous acid gas, which is very useful for bleaching straw and leghorn hats, and other articles.

The process of bleaching straw, as practiced by milliners, you have probably observed. When carried on in a small way, the sulphur with a hot coal is placed in a dish upon the bottom of a barrel, and sticks are laid cross wise for the hats, or articles which are to be bleached, to rest upon. The barrel is then covered with some thick cloth, to prevent the sulphurous acid gas which rises, from passing off.

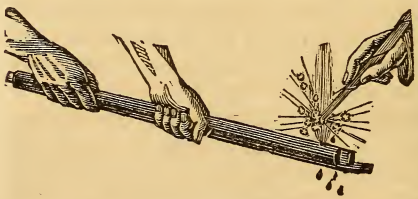
Iron moulds and the stains of vegetables may be removed in this way. Articles for bleaching must be wet with water. In the large Manufacturing establishments, where cotton cloth, yarn, and other articles on a great scale are to be bleached, they are hung wet upon frames in tight apartments, having floors of sheet lead, on which the sulphur is burned.

In what two states is sulphur usually known?
What takes place when sulphur is thrown upon coals?
How do milliners bleach straw and leghorn hats?

Other uses of Sulphur.

The most important use of sulphur is in the composition of gun-powder, in which it is mixed with charcoal and salt-petre. The effects of gun-powder are owing to the sudden change of the solids which compose it into gases. Sulphur is used in medicine externally to cure diseases of the skin, and internally as a cathartic. It is used to copy medals by being melted, and then poured into hot water; in this state the medals are impressed upon it, and leave their impression. Small pine sticks, dipped in melted sulphur, form matches used for kindling fires.

If a bar of hot iron is rubbed with a roll of brimstone, the iron will melt and fall to pieces.



The figure shows a gun-barrel heated to redness, having a piece of sulphur placed at one end, which is then closed. The sulphurous vapour issuing forth at an orifice near this end of the gun-barrel burns a bunch of iron wire which is held over it, so that it falls in melted globules. These are a *sulphuret of iron*, so called from being a combination of iron and sulphur.

Beautiful crystals of sulphur for ornamental articles, may be made by melting it in a deep vessel. The surface will become solid; this must then be broken and the liquid below turned off.

Sulphur melts or fuses at 218° of heat. At 600° of heat, it *sublimes*; that is, it becomes a vapour, and settles

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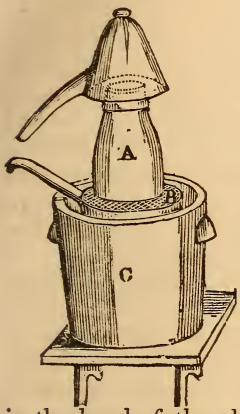
What are some of the uses of sulphur?
What is represented by the figure?
How may crystals of sulphur be obtained?
What degrees of heat are required for melting and subliming sulphur?

again on the sides of the vessel which is placed over it for that purpose.



In order to obtain it purified from the earths, and metallic substances with which it is often combined, sulphur is distilled or sublimed in a vessel called an *alembic*, as here represented. The sulphur is put into the lower part, A, this is then placed over a vessel of sand B, called a *sand-bath*, which is heated by a furnace C: by means of the sand-bath the sulphur is fused more gradually and equally, than could be done by placing it directly over a fire. When heated to a sufficient degree, the sulphur rises in the form of a thick, white vapour and settles in the head of the alembic, in clusters resembling *flowers;* from this has been derived the term flowers of sulphur, though some from its fineness call it the *flour* of sulphur. Vessels of this kind are used in *distilling*, and the tube, which appears in the upper part of the alembic, is useful in conducting the distilled substance into a receiver. The product of sublimation is a solid, that of distillation a liquid.

Sulphur possesses the *positive* electricity; it therefore goes to the negative pole of the galvanic circle.

The weight of its atom is reckoned as 16, hydrogen being unity, or 1.

COMBINATIONS OF SULPHUR AND OXYGEN.

We are now to consider sulphur as united with oxy-

How is sulphur sublimed?
Why does sulphur go to the negative pole of the galvanic circle?
What is the weight of its atom?
What two important substances are formed by the union of sulphur with oxygen?

gen; and here we find two important substances, sulphur*ous* and sulphur*ic* acids. The ending in *ous* shows a lower proportion of oxygen, the ending in *ic* shows a higher proportion.

Sulphurous Acid.

We have already made some remarks upon the gas which results from the burning of sulphur in atmospheric air; you will recollect that this is the *sulphurous acid* gas. One atom of sulphur, 16, is here united to two of oxygen, the sum of which being also 16, makes the equivalent of sulphurous acid 32. Sulphurous acid is obtained for observation in a class, by suspending burning sulphur in a glass bottle containing a little water. The sulphurous acid gas uniting with the water gives it acid properties which may be ascertained by the taste, which is disagreeable and peculiar to this gas. By mixing blue vegetable infusions with this liquid it will be at first reddened and then the colour will be entirely destroyed.

A red rose dipped in water containing a sufficient quantity of this gas loses its colour and becomes white; pieces of calico which have been dyed with vegetable colours, become white on being wet with this liquid. But we have already spoken of the uses of sulphur in bleaching, or destroying the colours of different substances; you will however observe, that it is only when combined with oxygen in the proportion to form the gas we are now considering, that it has this effect.

In the *an*hydrous state,* sulphurous acid is in the form

* That is, without water.

What is the equivalent number of sulphurous acid, and how may this be obtained in a liquid state?

What change is produced upon vegetable colours by immersing substances in sulphurous acid?

How does sulphurous acid appear when not combined with water?

of a gas without colour, and having a strong smell. It is suffocating to the lungs, and destroys combustion.

Sulphuric Acid.

We have in sulphuric acid a combination of suphur with its highest proportion of oxygen; or, 1 atom of sulphur=16, united to 3 atoms of oxygen=24, makes the equivalent of sulphuric acid=40.

This acid was formerly called *oil of vitriol;* it has been known since the fifteenth century, and is now a very important article, not only in the laboratory of the chmeist, but in the manufacture of other substances. Nitric and muriatic acids are prepared by the assistance of sulphuric acid.

Modes of obtaining Sulphuric Acid.

Experiment.—You have seen that sulphur burned in atmospheric air does not unite with a sufficient portion of oxygen to form sulphuric acid; neither if burned in pure oxygen gas will it form any thing more than sulphurous acid. In order to illustrate the formation of sulphuric acid, four parts of sulphur being mixed with one of nitre (salt-petre,) may be burned in a glass bottle containing a little water, in the same way as for obtaining sulphurous acid. The water, though slightly sour, will exhibit the properties of weak sulphuric acid, and be very different as to taste from the sulphurous acid.

In preparing this acid for commerce, large quantities of sulphur and salt-petre in the proportion of 8 of the former to 1 of the latter, are burned in chambers lined with sheet lead. The mixture being placed in a vessel upon

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In what proportions does oxygen exist in sulphuric acid?
Has this acid been long known, and is it a useful substance?
How may the formation of sulphuric acid be illustrated?
How are large quantities of sulphuric acid prepared for commerce?

the leaden floor, which has been covered with water, is inflamed; in burning it consumes the oxygen of the air. New portions of the sulphur and salt-petre are added from time to time, and fresh air admitted into the chamber. The sulphuric acid gas is absorbed by the water upon the floor of the chamber; this is afterwards distilled in order to obtain the acid in a pure and concentrated state.

The explanation of this process is this: sulphurous acid is first formed by the burning of the sulphur in the air, the nitre furnishes another portion of oxygen, and the sulphurous thus becomes sulphuric acid.

Some of the properties of sulphuric acid you have already learned—you have seen that many substances have so strong an affinity for it that they leave their old combinations to form with it new ones. Thus muriate of soda, became sulphate of soda, and muriate of lime, sulphate of lime. As we proceed, we shall find that it unites with metals, forming substances called *sulphates*, while the sulphurous acid uniting with metals forms *sulphites*.

Sulphuric acid is one of the most corroding substances in nature. I could show you a book, which now lies before me, that seven years ago happened to have one drop of this acid fall upon it; at first it only made a brown stain, but it has continued to eat gradually until a great many pages have been partly consumed; or, I should rather say, have been *burned*, since the effect is produced by the action of oxygen upon the paper, and indeed its appearance is exactly what it might have been, if burnt slowly by a hot coal. Thus in the course of time, one drop of this acid will consume the whole book. You will I hope be very careful in its use, should you attempt to perform experiments with sulphurous

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How is this process explained?

Does sulphuric acid combine freely with other substances?

What instance is mentioned to prove the corrosive nature of sulphuric acid?

acid, and not suffer it to fall upon your clothing, and especially any part of your person.

But should such an event occur in consequence of any accident, you will remember that while water only serves to excite the acid to action, chalk, lime, or any alkaline substance neutralizes it, and of course alleviates its effects. When swallowed accidentally, chalk and magnesia are the best remedies. But every person who makes use of this, or any other active substances, should be very careful to have it conspicuously labelled.

When sulphuric acid is decomposed by galvanism, the sulphur goes to the negative, and the oxygen to the positive pole.

Combining Weight.

It was mentioned that sulphur was considered as represented by the number 16, it being so much heavier than hydrogen which is taken as a unit, or 1. Oxygen is 8; therefore the two acids we have been considering may be thus stated;—*sulphurous acid* composed of 1 part sulphur 16, and 2 parts Oxygen 16=32. Sulphuric acid composed of 1 part sulphur 16, and 3 parts Oxygen 24=40.

We see, that the number 32, stands for the lower acid, and 40 for the higher acid.

We have now closed our remarks upon the compounds of sulphur with oxygen; we shall hereafter notice *sulphates*, *sulphites*, and *sulphurets*, which are compounds of sulphuric acid and sulphur with metals, alkalies, and earths.

What are the most proper applications in case of accidents with sulphuric acid?

When sulphuric acid is decomposed by galvanism, to which pole is each element attracted?

What is said respecting the combining weight of the atoms of sulphur &c., and of the numbers which stand for sulphuric and sulphurous acid?

SELENIUM.

Before closing this chapter we will introduce an *element* which being considered as simple, should not be omitted; though little can be said of it to interest the beginner in Chemistry. Selenium was discovered in 1817, by the Swedish chemist, Berzelius. It was by him considered as a metal; but as it is found to be a bad conductor of electricity and caloric, which is not the case with the metals, it is not at present ranked as such.

Selenium is found in connexion with various metals, as lead, silver, copper and iron. It was first discovered in iron pyrites, (sulphuret of iron,) which are used in Sweden for the manufacture of sulphuric acid. A reddish substance was observed to remain, after the process for obtaining the sulphur was completed. On burning, a smell like that of horse-raddish was given off. Berzelius found it to resist all attempts to decompose it, and therefore classed it among the elementary substances.

Its properties in some respects resemble sulphur.—When powdered, its colour is reddish, but when broken in larger masses, its fracture is metallic. It is soft like wax. Its combinations are not numerous or important, at least as far as is now known respecting it. With oxygen it forms *selenic* and *selenious acids.*

When and by whom was selenium discovered?
What circumstances led to its discovery?
What are its properties?

CHAPTER XIII.

Phosphorus. Impositions practiced by means of Phosphorus. Eudiometer of Phosphorus. Phosphorus and Oxygen. Phosphorus and Hydrogen.

We now commence the observation of another simple substance, which though less commonly known than the one we have last examined, constitutes a portion of our own frame, it being found combined with other substances in large quantities, in animal bones and teeth.

The word Phosphorus is derived from the Greek words *phos* light, and *phero* to bear, and signifies light-bearer.

Notwithstanding the existence of this substance is as ancient as the creation, it was not discovered until the year 1691, when Brandt, an alchemist of Germany, accidentally obtained it. The reason of its being so long unknown, is, that it is intimately combined with other bodies, and can only be separated from them by a long process.

Bones contain phosphorus united to oxygen and lime, forming a compound which is called *phosphate of lime.*

The phosphate of lime consists of *phosphoric acid* and lime. In order to obtain pure phosphorus, the lime, and

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What substances contain phosphorus?
What is the word phosphorus derived from?
Has phosphorus been long known?
What substances contain the *phosphate of lime?*
How may pure phosphorus be obtained from the phosphate of lime?

the oxygen of the phosphoric acid, must be disposed of. As you are not yet chemists enough to attempt the manufacture of this article, it is not necessary that you should study the operations which this requires; these chiefly depend on that great principle of chemical affinity which we have endeavored to explain. First, one substance is attracted from the phosphorus by presenting another for which it has a greater affinity, and then the other substance is withdrawn in the same manner.

Every lecturer who makes experiments in chemistry does not prepare the phosphorus he uses. This is obtained from the shops in the form of yellowish sticks, smaller than a pipe's stem and a few inches in length. It cannot be put up in papers and handled like most other solid substances which we purchase. It is usually kept in vials of water, because when exposed to the air, and the slightest increase of temperature, it takes fire.

When you see phosphorus, that has for some time been kept in water, you may observe that the sticks are covered with a whitish crust; this is an *oxide of phosphorus.* It is formed by the attraction which this substance has for oxygen, which it takes from the water; it is still more combustible than pure phosphorus. If exposed to the sun, it takes fire spontaneously.

Impositions practised by the use of Phosphorus.

In former times, wicked and and artful people imposed greatly upon the ignorant, by means of the peculiar properties of phosphorus; for instance, words written on a board, with a stick of this substance, will, in the dark,

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In what form is phosphorus usually obtained for chemical experiments?

What is the whitish crust that covers the sticks of phosphorus?

In what manner have impositions been practised upon people by the use of phosphorus?

appear like the words of fire. It is said the monks of early days, who possessed nearly all the knowledge of chemical substances which then existed, sometimes practised upon the credulous novice, by making him believe he saw the devil with flames about his head and ready to take possession of him if he refused to pronounce monastic vows. By dissolving phosphorus in oil and rubbing the face and hair with it, it produces, in the dark, the appearance of a glowing fire, playing over the features, and issuing from the head. It does not burn the skin, if the phosphorus be thoroughly mixed with the oil. *

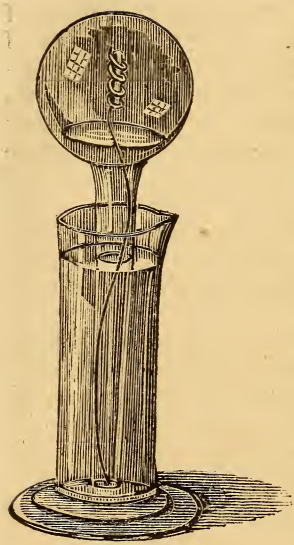
It is the great affinity which phosphorus has for oxygen that causes the phenomena, we have described; this affinity is so great, that by uniting with its oxygen, phosphorus burns when exposed to air of an ordinary temperature. The burning, or combustion, in this case is very slow, and is not painful or injurious to the skin. Inflamed in pure oxygen gas, phosphorus burns with the most vivid brilliancy.

Eudiometer, or the purity of the air, tested.

By the use of phosphorus, the purity of the air is tested in the following manner:—an instrument, called an *eudiometer*, which is represented on the next page, shows a glass matrass inverted in a jar of water; a coil of wire supports a stick of phosphorus. By degrees

* A fine young lad, the son of a distinguished chemist, was, a few years since, badly burned in consequence of a failure in this respect, when showing this property of phosphorus before a class of young ladies. Although he suffered much from pain he went through with the exhibition without complaint.

What causes the phenomena which have been mentioned? Describe the eudiometer.



the phosphorus unites with all the oxygen of the air in the glass vessel, leaving only nitrogen, while water ascends to fill the place of the gas which has been absorbed. The quantity of oxygen which the air contained, is ascertained by a knowledge of the quantity of air which was included, and the quantity which has united to the phosphorus; for you must remember that none of the nitrogen is absorbed by it. When the air of any place is found to contain less than the usual proportion of oxygen, it is pronounced impure. The term *eudiometer*, is derived from the Greek, and signifies health of the atmosphere.

Substances which contain phosphorus, and its uses.

You may well suppose that a substance so combustible as phosphorus does not exist in a free state in nature; it is always obtained by analyzing some of its compounds, usually the phosphate of lime. Combined with oxygen it enters into combination with many minerals; it exists in the nerves and brains of fish, which on this account often have a luminous appearance in the dark.

It is not an important substance as respects its application to the arts. It is used in making phosphoric matches, and as we have just seen in testing the purity of the air. Attempts have been made to use it in medicine, but its effect upon the animal organs is said to be injurious.

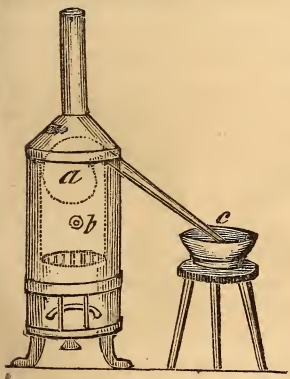
Is phosphorus found in nature in a pure state?
Is it of important use in the arts and in medicine?

Combination of Phosphorus and Oxygen.

There are two acids formed by the union of oxygen and phosphorus; viz. *phosphorous* and *phosphoric* acids.

1. *Phosphorous acid;* this is obtained by the slow combustion of phosphorus in the air; its properties are not remarkable. In combination with other substances it forms *phosphites.*

2. *Phosphoric acid;* this is obtained by the burning of phosphorus under a bell glass in oxygen gas. The bell glass containing oxygen, is set in a shallow vessel containing a little water, and the phosphorus is placed upon a small cup raised from the bottom of the vessel. On being inflamed with a taper it burns rapidly and with great brilliancy. The bell glass, is filled with a white vapour resembling a snow storm in miniature; white flakes then fall to the bottom of the vessel, these are phosphoric acid.



The oxygen may be expelled from this acid, and phosphorus again obtained by heating it with charcoal.—The figure shows you a retort *a*, placed over a furnace *b*. The retort which contains phosphoric acid and charcoal, has its tube immersed in the basin of water *c*. Large quantities of gas, carbonic acid gas, which is composed of oxygen from the phosphoric acid, united to a gas which proceeds

What two acids are formed by the union of oxygen with phosphorus?

How is phosphorous acid obtained?

How is phosphoric acid obiained?

from the charcoal, pass over. When the retort is at a red heat, phosphorus in the form of a reddish wax, appears in the basin of water.

The weight of an atom of phosphorus, being in relation to the weight of an atom of hydrogen, 12; its two acids are thus expressed. Phosphorous acid; 1 part phosphorous, 12, and 1 part of oxygen, 8, this is represented by the number 20.

Phosphoric acid; 1 part phosphorous ,12, and 2 parts oxygen, 16, this is represented by the number 28.

Combination of Phosphorus and Hydrogen.

In combination with hydrogen phosphorus forms a substance called *phosphuretted hydrogen.*

Here we have two simple *combustible substances* united. You will observe that the termination *uret* or *uretted* is used to denote this union.

Phosphuretted hydrogen may be obtained by heating phosphorus with a solution of potash, and collecting it through a solution of the same kind, instead of water.

How may phosphorus be obtained from phosphoric acid?

By what numbers are the acids of phosphorus expressed?

What substance is formed by the union of phosphorus with hydrogen?

What does the termination *uret* denote?

How is phosphuretted hydrogen obtained?

Part of the phosphorus unites with the potash—hydrogen is given off from the solution, and unites with another portion of phosphorus, forming phosphuretted hydrogen gas. This gas passing from the beak of the retort into the solution of potash rises into air, where it inflames spontaneously. Each bubble of gas after exploding ascends in the form of a pale wreath of smoke becoming fainter and larger as it rises.

This gas is produced in nature by the decomposition of animal substances in which the two elements exist abundantly; particularly in the brains and nerves. Thus when a body is buried, as the animal matter putrifies, hydrogen and phosphorous in a gaseous form escape and uniting pass up through the earth, and ascend into the atmosphere; owing to the peculiar nature of this gas, it takes fire at the ordinary temperature; thus it happens that over grave yards, lights are sometimes seen, which, the ignorant are ready to believe are the spirits of the departed, or indicative of some unearthly visitation. Children not unfrequently hear about *Jack-o'-lanterns*, or wandering spirits which lead people into bogs and marshes and then disappear. It is in damp grounds that the phosphoretted hydrogen is most likely to be formed, and we can therefore see the reason for the Jack-o'-lantern leading its followers into such places. Professor Silliman says, 'travelling once through a deep valley in a dark night, I was surrounded by multitudes of pale, lambent lights; they were every moment changing their position and some of them were within reach of my whip.'

You see how knowledge serves to remove from the mind those superstitious fears which torment it, when ignorant of the causes of the phenomena of nature. It was this ignorance which gave rise to a belief in the existence of witches and hobgoblins of various kinds. By means of knowledge man has subjected the elements of

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How may the lights be accounted for which often appear in damp grounds, grave yards, &c.

What are some of the effects of knowledge?

nature to his sway; and although no witches ride through the air on broomsticks, yet people do fly in balloons. ride with almost the rapidity of lightning in rail road cars, or glide, with the swiftness which might be ascribed to the motion of spirits, in steam boats. All this is the effect of knowledge.

CHAPTER XIV.

Carbon—Cabonic Acid, and Carbonic Oxide.

THE subject of our lesson is *Carbon;* the word is derived from *carbo* a coal. This exists in all vegetable and animal matter, being one of the most extensively diffused substances in nature.

You are familiar with *charcoal;* you know it is what remains of wood after it has been exposed to heat. The common charcoal which is used in household operations is made by placing sticks of wood in a conical pile, covering them with earth, and kindling a fire in an opening below. The volatile parts of the wood are driven off by heat and make their way through apertures in the covering, and charcoal remains. This is nearly *pure carbon.*

Diamond.

In the diamond you may see pure, crystalized carbon. But diamonds are very rare in our country. There is a great deal of jewelry which is made in imitation of dia-

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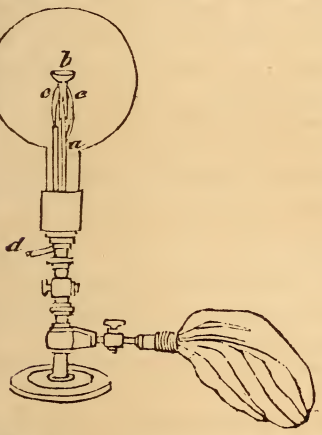
What element is the subject of this lesson, and where does it exist?

What is charcoal, and how is it obtained?

monds, but the real diamond possesses a splendour that cannot be imitated. The empress Catherine of Russia, gave 100,000 pounds for a diamond about the size of a pigeon's egg, which was placed in the imperial sceptre.

Sir Isaac Newton suggested that the diamond might be made to burn, because its power of reflecting and refracting the rays of light was so great; and where a body was capable of producing such effects on light, he thought it must be affected by caloric. It is now proved that the diamond is a combustible substance.



This figure showsan apparatus for burning diamonds, *a*, is a small tube, which is to convey a stream of hydrogen upon the diamonds which are placed in the little platina grate *b*; at *ee*, are two wires which are designed to inflame the jet of hydrogen by communicating electricity, which they receive from a machine by means of a ball, *d*, in which they terminate. When the apparatus is used, the diamonds being placed upon the platina grate, the glass globe which surrounds it is first exhausted of air by means of an air pump, and then filled with pure oxygen; sparks of electricity are now communicated to the ball connected with the wires, and a current of hydrogen thrown up by turning a stop cock, and pressing a bladder which contains this gas. The platina dish and the diamonds are first heated

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Whet is the real diamond composed of, and what is said of its value?

What led Sir Isaac Newton to think the diamond might be made to burn?

to a white heat, and then the diamond begins to burn.—The stop cock is now turned to prevent the passage of more hydrogen, and the diamonds will continue to burn till consumed. The product of this combustion of diamonds in pure oxygen is *carbonic acid gas.* This experiment proves that the diamond is composed of carbon.

You might suppose that since chemists know of what they are composed, and as this material is very abundant in nature, they could *manufacture* diamonds; but you must recollect that they are *crystals of carbon*, and no method of bringing carbon to this state is known. Scientific men, stimulated by the desire of making discoveries, and artists eager for wealth have sought to ascertain a mode of crystallizing carbon, but like the alchymists of former days, who endeavoured to turn stones into gold, they have been disappointed in the attempt to make diamonds from charcoal, although the substances which compose them are the same.

You must not confound with charcoal the various kinds of coal which are dug out of the earth; the latter are called mineral coal. They contain a large proportion of carbon, but usually mixed with some sulphur and iron. They are heavier than charcoal.

Black lead or *plumbago*, lamp black, and soot are chiefly composed of carbon.

In considering the properties of carbon, we shall confine ourselves to that form of it which is seen in *charcoal.*

1. It is remarkable for its power of absorbing gases of different kinds, and giving them off again when heated. When newly made, its pores become filled with the first kind of air or gas which comes in contact with it. In order to purify it from these sub-

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Describe the process for burning diamonds.
Can diamonds be manufactured from carbon?
Are all kinds of coal called charcoal?
What substances besides coal are chiefly composed of carbon?
What is said of the absorbing power of charcoal?

stances it must be heated, when it is again ready to absorb other gases. These gases do not form a chemical combination with charcoal, or alter either its properties or their own; for when driven off by heat and collected, they are found to be unchanged, and to leave the charcoal so.

2. A very important property of charcoal is that of destroying the smell, taste, and colour of many substances. It is one of the most important antiseptics* known. It will purify water that has become putrid, and for this reason is very useful to persons at sea, who cannot obtain fresh water. Tainted meat may be made sweet by being boiled with powdered charcoal, or rubbed thoroughly with it. But the house-keeper who uses it for this purpose must remember that it must be heated to redness, and applied to the meat before it has absorbed other gas than the putrid odour of the meat If put into water while hot, it may be thus preserved fit for use. On account of its antiseptic nature, it makes an excellent dentrifice.

3. Charcoal resists decay; for this reason the ends of posts which are to be put into the ground are charred or burnt. Silliman remarks, that he saw in the British Museum, at London, a pointed stake, which, with many others, was found in the bed of the Thames, in the spot where, according to the Roman historian, Tacitus, the Britons fixed a vast number of such stakes to prevent Julius Cæsar from passing with his invading army. They were all charred to a considerable depth, and retained their form entirely; they were so firm that knife

* Antiseptic is derived from the Greek *anti*, against, and *septo*, to putrify; an antidote to putrefaction. Whatever possesses the power to prevent animal substances from putrefaction, or removes it after it has commenced, is called an antiseptic.

What is said of the purifying power of charcoal?

Why are the ends of posts sometimes charred, or burned before they put into the ground?

handles were manufactured from them, and sold at a great price.

Uses of Carbon.

Charcoal in the form of lamp black, is used with oil for paints, and printer's ink; with iron it forms steel; with sulphur and nitre it makes gunpowder. It is in common use for fuel, and especially in cooking operations of various kinds. The *diamond* furnishes not only the most elegant ornaments, but is useful in the arts; it is the best substance known for cutting glass.

Combination of Carbon and Oxygen.

We here meet with a gas which exists in a vast number of substances, which we throw out of our lungs at every breath, and yet which we cannot inhale in any large quantity without destroying life; this is *carbonic acid gas*, sometimes called *fixed air*, because it exists in a fixed state in lime and many other minerals.

Modes of obtaining carbonic acid gas.

By burning diamond or charcoal in oxygen gas, pure carbonic gas is obtained. But the burning of diamonds is too expensive an operation to be performed except for important experiments, and the gas can be obtained still more easily than by burning charcoal in oxygen.

There are in nature many *carbonates;* that of lime under varions forms, as limestone, marble and chalk is the most common. Carbonates are composed of carbonic acid gas, united to some substance called its *base;* thus lime is the base of carbonate of lime.

What are some of the uses of charcoal?

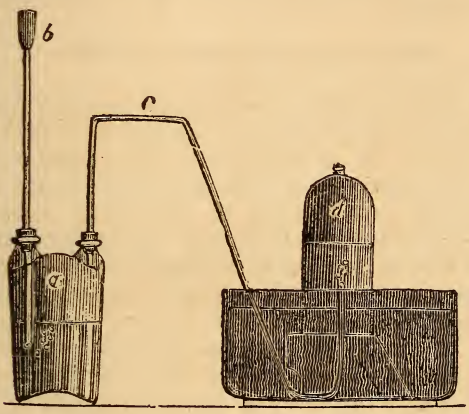
What gas is it which we exhale in breathing, but which cannot be inhaled in any large quantity?

Is carbonic acid usually obtained by burning either diamonds or charcoal in oxygen gas?

What are limestone, marble, and chalk?

The common method of obtaining carbonic acid gas is, by the decomposition of chalk or powdered limestone, by means of sulphuric or muriatic acid.

In the figure, the bottle *a* is supposed to contain pieces



of marble or any other carbonate of lime; through the tunnel *b*, is poured weak muriatic or sulphuric acid—a violent effervescence takes place owing to the escape of carbonic acid, which passes through the tube *c* into the bell glass *d;* the receiver is not filled with water, with which carbonic acid gas would unite; but it excludes the common air. Carbonic acid seems held to its bases by a tie which is easily broken, for there are few acids which will not expel it from its combinations—thus vinegar poured upon pearlash, which is a carbonate of potash, causes the carbonic acid to pass off; its escape is indicated by the effervesence that takes place. This is owing to *elective* affinity. The acid which makes vinegar is called *acetic* acid, for this, the potash has a greater affinity than for the carbonic acid which is expelled.

What is the common mode of obtaining carbonic acid gas?
Is carbonic acid easily separated from its gases?

By means of *heat* only, the carbonic acid may be driven off from carbonates. Thus quick lime, which is used for white-washing and plastering is made from limestone, by heating the latter in kilns, and thus expelling the carbonic acid gas.

Properties of Carbonic Acid Gas.

No animal can live in an atmosphere of this gas. Insects, to be preserved, may be confined in it, as they will die at once. It is different in its effects upon the lungs from nitrogen or hydrogen, they do not support life, carbonic acid *destroys* it. In the two former, animals die for the want of oxygen, in the latter they are killed. It is on account of the deadly nature of this gas, that charcoal is so dangerous when burnt in a close room. The small portable furnaces which are now so much in use for cooking, ironing, and other household operations, should never be used except in the open air, or in a fire place, and then the doors of the room should be opened. Three young women a year or two ago, were ironing in a close room, with furnaces to heat their irons, and all of them fainted successively. The charcoal, as it burns, gives off carbon, which, uniting with the oxygen of the air, forms carbonic acid gas.

Carbonic acid gas does not support combustion; a lighted taper suspended in it is immediately extinguished. This fact should be known to all;—lives are often destroyed in consequence of people going into wells and vaults where this gas abounds; sometimes when one person faints others go immediately into the same place, and many lives are thus lost in consequence of ignorance. If people would first test the purity of such places by suspending into them a lighted candle, they would at once know whether they could live in them;—if

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How is quick lime manufactured?

Will an atmosphere of carbonic acid gas support life?

How can the existence of this gas be ascertained in wells and other places?

the air will not support combustion, it will not support life, or rather if it destroys the one, it will destroy the other.

Carbonic acid gas is *heavier* than atmospheric air; this is the reason why it is most abundant in low places. It sinks into them.

It may be poured from one vessel to another like liquids. If you collect this gas in a tumbler it may stand without being covered, for it will not rise and escape like most other gases. It is a curious experiment to see a lamp extinguished by holding over it what appears to be an empty tumbler; for carbonic acid gas is without colour and invisible, yet it may be thus poured out upon a flame, and it will destroy it as if it were so much water.

This gas is called carbonic *acid*, because it gives to liquid substances an acid taste of a peculiar kind, which, though not sharp, is lively and refreshing. It is this gas which sparkles and bubles in good bottled cider and some wines. It causes the effervesence and refreshing taste of soda waters, and the smartness of the Saratoga and some other mineral waters.

Carbonic acid gas unites with water and imparts to it a peculiar taste. The soda fountains, in which carbonated water is prepared, are sometimes constructed as you see in the next figure. Pieces of pounded chalk or marble are put into a vessel* and sulphuric acid poured upon them;

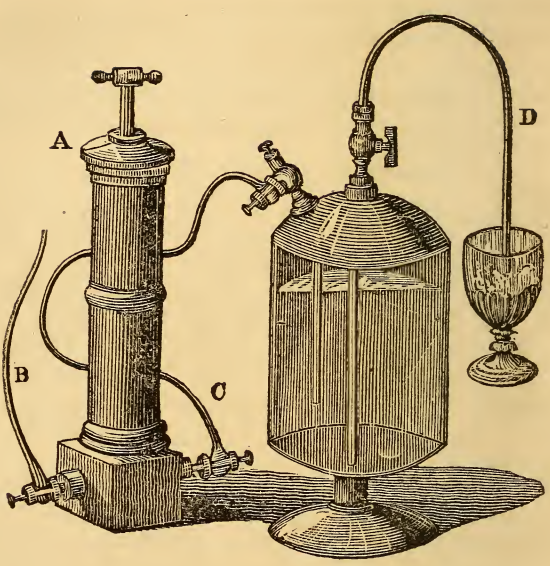
* Having shown the manner in which the gas is obtained, it is unnecessary to have the whole apparatus here exhibited. The pipe B, is supposed to communicate with the vessel from which the gas issues. See the figure on the next page.

Why is this gas most abundant in low places?

How can it be proved that carbonic acid gas is heavier than atmospheric air?

Why is it called carbonic *acid* gas?

How are soda fountains constructed?



the carbonic acid gas rapidly escapes into the tube B; at A, is a part of the apparatus called a *condenser* which draws in the gas from the pipe B, and forces it through the other pipe C, into a vessel containing the water. By means of pressure, water is made to absorb large quantities of this gas; when sufficiently impregnated with it, the water is drawn out by means of the syphon or bent tube D, and flows into the tumbler, where it appears sparkling and foaming. This is improperly called soda-water, since it usually contains no soda.

The peculiar properties of yeast or emptyings are owing to this gas. In struggling to escape through the wet flour, or dough of which bread is made, the carbonic

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Why do yeast and pearlash make bread and cakes light?

acid gas becomes entangled and causes the little cavities which appear in light bread. Pearlash makes cake light, on account of the carbonic acid gas which it contains.

Existence of this gas in nature.

Carbonic acid gas forms nearly half of the marble and limestone which are so abundant in the mineral kingdom, forming beds and mountains;—it is thrown from the lungs of animals in breathing;—it is produced by the fermentation of liquors, and the burning of candles, lamps, furnaces, and fire-places. Oysters and other shell fish have a covering of carbonate of lime, which seems to be formed from matter partly furnished by their own bodies, and partly by the salt water.

It would seem as if so deadly a gas, as we find the carbonic acid to be, in its effects upon animal life, and produced as it is, in such great abundance, from the breathing of animals, the decomposition of substances, and the burning of candles and fires, would soon destroy the whole animal creation. Besides, we use oxygen at every inspiration or drawing in of the breath;—does it not seem alarming to think of the great quantities of the deadly air which is every moment formed, and the vast portions of the vital air which are at the same time consumed? Behold here the wisdom of God, who, when he formed the grass, the herb and tree, and gave them to man for meat, so made them, that in their growth, they should absorb and be nourished by this very gas, so fatal to the life of animals; and, at the same, time throw from their vegetable lungs, that gas, without which, they would instantly die! Truly, God gave the vegetable world for meat, in more senses than one; and well might He, in beholding his work, and its curiously balanced machinery, pronounce it 'good!'

Is carbonic acid gas found extensively in nature?

Why does not the accumulation of carbonic acid, and the constant waste of oxygen, destroy the whole animal creation?

The weight of an atom of carbon is reckoned as 6, that of hydrogen being 1.

Carbonic acid being composed of carbon 1 atom=6
oxygen 2 " 16

The number which represents it is 22

This is called its chemical equivalent.

Carbonic oxide gas.

There is a combination of carbon with oxygen, called *carbonic oxide;* in which the proportion of carbon is much greater than in the gas we have been studying; indeed, the term, *oxide,* denotes that the substance contains less oxygen than is required to form an acid.

Carbonic oxide is no less fatal to animal life than carbonic acid. The great chemist, Sir Humphrey Davy, of England, who often exposed his life, in his zeal for making discoveries, once attempted to inhale it, mixed with one fourth part of common air, but the attempt had nearly proved fatal. Another person, attempting to breathe it, appeared to fall into an apoplexy, from which he was restored by inhaling oxygen gas. You see how much men of science expose themselves, that they may learn the nature and properties of substances;—and unless they did so, of how many facts should we now be ignorant that are of importance to the world.

You will recollect that 22 is the representative number of carbonic acid. Carbonic oxide being composed of one part of carbon 6, united to one part oxygen 8, 14 is the representative number of this gas;—one additional part of oxygen, being 8, would change it into carbonic acid gas.

What is the weight of an atom of carbon?

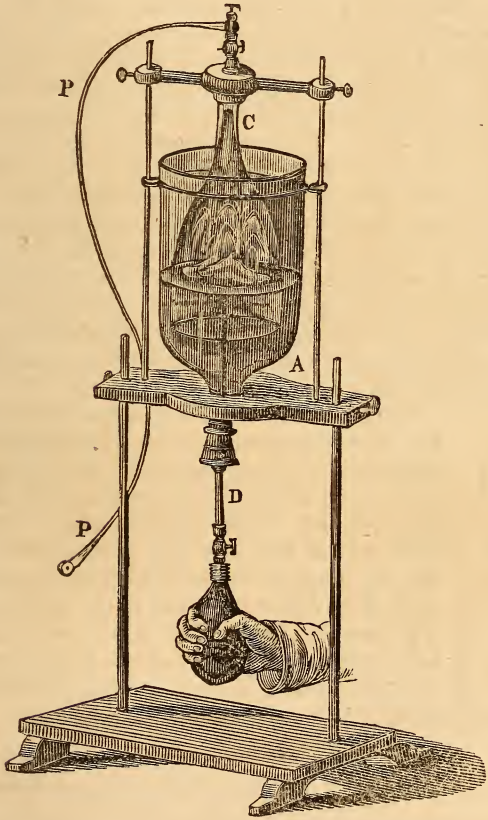
What is the chemical equivalent of carbonic acid?

What combination is there of carbon and oxygen besides the one we have just been examining?

What is the effect of carbonic oxide when taken into the lungs?

What is the representative number of this gas?

Carbonic oxide is obtained by heating chalk and iron-filings to a red heat. The chalk furnishes carbonic acid, but the iron, having a great affinity for oxygen, takes some portion of it from the carbonic acid, and reduces it to carbonic oxide. The two gases pass off together, but by washing them with lime water, all the carbonic acid



How is carbonic acid obtained?

unites with it, forming carbonate of lime, while the carbonic oxide is left in the state of a pure gas. The figure, on the last page, represents an invention of Dr. Hare for separating the two gases, by means of lime water. The gun-barrel, and furnace for heating the chalk and iron filings is not here described, but the pipe ***P*** is supposed to communicate with a reservoir of the mixed gases; that is, the carbonic acid and carbonic oxide. The gases are introduced into the upper bell glass ***C***, by turning a stop-cock which is between that and the pipe ***P***. The lower pipe ***D***, communicates with the bell glass ***A***, and has, affixed to it, a gum elastic or Indian rubber bag. The two gases, carbonic acid and carbonic oxide, are now introduced into the bell glass ***C***, which had been previously filled with lime water; this, as the gas enters from the pipe, sinks into the lower bell glass. By means of pressure from the hand, upon the gum elastic bag, jets of lime water are thrown up into the gas in the upper bell glass. All the carbonic acid unites with the water, while the carbonic oxide is left pure, and may be transferred into any receiver by means of the pipe.

Carbonic oxide will not support combustion; but it is inflammable, and will, itself, burn in oxygen or in common air. But the product of its combustion is not water as in the case of hydrogen; it is carbonic acid. You may here see an inverted jar, placed over a vessel of carbonic oxide which is burning in a jet, as it issues from the tube, at the mouth. The inverted jar will be filled with carbonic acid gas. The air furnishes another atom of oxygen (8) which, uniting with the carbonic oxide, (14), makes carbonic acid (22).

Describe Dr. Hare's invention for obtaining carbonic oxide pure?

When carbonic oxide gas burns in air or water, what is the product of this combustion?

CHAPTER XV.

Boron. Iodine. Fluorine. Bromine.

THERE is a substance known in commerce by the name of *borax;* it is found abundantly in various parts of Asia, especially in the East Indies, from whence it is exported to Europe in large quantities, under the name of *tincal.* It is found in crystalline masses, resembling alum, a yard, or more, beneath the surface of the earth, sometimes obtained by evaporating the waters of certain lakes, or found in a solid form at the bottom of lakes; which is the case in the salt lakes of Peru.

But borax is a *compound* substance, consisting of an acid called *boracic* * acid,—united to soda as its base; it is a *borate of soda,* and is classed among the salts.

In 1702, a chemist in Paris, discovered in borax, the boracic acid. It is obtained by adding sulphuric acid, to borax or the borate of soda.

Experiment.—A small piece of borax is put into a vessel, and hot water and sulphuric acid poured upon it; it is then placed over burning coals for a few minutes. The borax decomposes, and a sulphate of soda is formed; this is in solution—on cooling, solid scales, of a white and shining appearance may be collected; these are boracic acid.

* Pronounced *borasic.*

Where is borax found?
Is borax a simple substance?
What acid is obtained from borax?
By what process is boracic acid separated from borax?

Explanation.—You will at once perceive here the agency of elective affinity; the soda having a greater affinity for sulphuric than for the boracic acid, unites with it and expels the latter.

But boracic acid itself is a compound; its base was discovered about one hundred years after the acid itself, by Sir Humphrey Davy. He found by heating the acid with a metal called potassium, that oxygen was liberated, and a dark, olive coloured mass remained. This he named *boron*, and as no succeeding chemist has been able to decompose it, it is ranked among the *elements*, or simple substances.

The weight of its atom is 8, the same as oxygen. In boracic acid, 1 part of boron 8, is united to 2 parts of oxygen 16; this makes the representative number of this acid 24.

Boron is a combustible substance, resembling carbon in some respects—the product of its combustion when burnt in the common air, or in oxygen gas, is boracic acid.

The figure, p. 161, shows the apparatus lately invented by Dr. Hare, for the purpose of obtaining boron from boracic acid; this acid, in a very dry state, is put, with the metal potassium, into a copper cup, supported by a cylinder of copper ***C***;—***A***, ***A***, are the rods which support the large receiver that is placed over the cup containing the boracic acid and potassium. One of the pipes ***P***, communicates with an air pump. The air being exhausted under the receiver, an iron heated to redness, is introduced through the cylinder ***B***, until it touches the bottom of the cup above the tube ***C***, which

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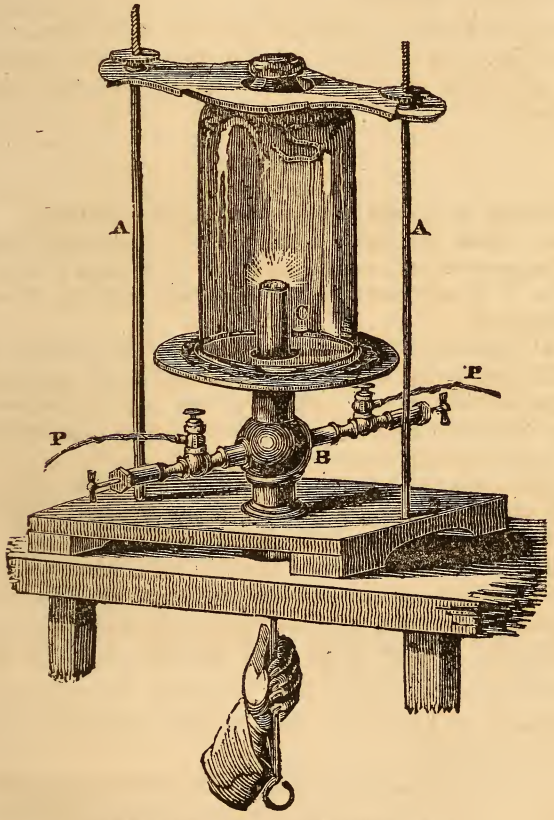
How is this explained?

How did Sir Humphrey Davy discover that boracic acid is a compound substance?

What is the weight of an atom of boron, and what is the representative number of boracic acid?

What is the product when boron is burned in oxygen or common air.

contains the boracic acid and potassium. When the cup is heated sufficiently, a deep red flame appears to cover the whole mass. On cooling, it is found that the potasium has taken from the acid its oxygen, forming the oxide of potassium, (or potash) while pure boron remains.



Describe the apparatus of Dr. Hare for obtaining boron.

Boracic acid, dissolved in alcohol, burns with a peculiar flame, the edges and top being of a beautiful green colour.

Uses of Borax.

Borax is used in the arts, to assist in the melting of metals and other substances, with some of which, it forms various coloured glass. It has been used in medicine, as a remedy for sore mouths, especially in the case of infants.

Iodine.

Boron, we found to be a *combustible* substance. *Iodine*, which we shall now consider, is ranked among the *supporters of combustion;* that is, though it does not burn, it is supposed to promote the burning of other substances.

All combustible substances possess the *positive* electricity, while the supporters of combustion, possess the *negative* electricity. Hitherto we have examined but one supporter of combustion, viz: oxygen, and this, for a long time, was considered the only one.

Iodine has been known only since the year 1812. It was discovered in Paris, by a manufacturer of soda, as he was burning sea-weeds to obtain this substance.

It exists in the form of a solid, of a gray colour; it is remarkable for its passing from a solid state immediately to that of a vapour, by a small increase of temperature. Almost every solid becomes a liquid before

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What is the appearance, when burning, of boracic acid dissolved in alcohol?

What are some of the uses of borax?

In what important particular does iodine differ from boron?

What is remarked of the electricity of combustible substances and supporters of combustion?

When and by whom was iodine discovered?

In what form does it exist, and for what is it remarkable?

it becomes a vapour; but this springs into vapour at once, or if it exists at all in a liquid state, the change is so sudden from that to a gaseous state, that it is not perceptible.

The name *iodine*, is from the Greek *iodes*, signifying violet-coloured. This is the colour of its vapour, which appears very beautiful when seen through a clear, transparent glass vial or bulb. Every one who can obtain at a druggists, a small piece of iodine, can, by putting it into a vial, have the pleasure of examining the curious effects which the heat of a common lamp almost instantly produces, since it is an experiment unattended with difficulty or danger. As soon as the vapour of iodine is withdrawn from heat, it returns immediately to its solid state, and gray colour, without appearing to have undergone any change in its nature.

Properties of Iodine.

Its odour is very disagreeable—its taste acrid. It is very corrosive, eating quickly through a cork, if a bottle containing it, is stopped by one—for this reason, glass stoppers are used. Its vapour is heavier than that of any other vapour; it being about nine times heavier than the air. The weight of its atom is 124. It destroys vegetable colours. With starch it produces a blue colour, a circumstance which always shows its presence.

Combinations of Iodine.

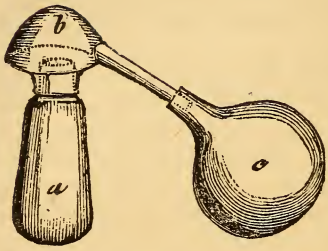
Iodine unites with oxygen, forming *iodic* and *iodous* acids, with hydrogen, forming *hydriodic* acid, and with metals, forming *iodides*. With soda, lime, and other alkalies, it forms *iodates*.

What is the colour of the vapour of iodine, and what does its name signify?

What are some of the properties of iodine?

What combinations does iodine form with other substances?

Method of obtaining Iodine.



The figure shows a flask *a*, which contains crystals formed by evaporating the ley of sea-weed ashes. Sulphuric acid is poured into the flask, and on the application of a gentle heat, the violet-coloured vapour of iodine, rises in the head *b*, and passes through the tube into the receiver *c*, where they are condensed into the solid gray substance, iodine.

Fluorine.

You will perhaps smile when you learn, that chemists have placed among the elements, a substance which does not exist, or, at least, which has never yet been obtained; the name which they have given to this imaginary element is *fluorine.*

There is a beautiful mineral found in England, called, from the place where it is the most common, Derbyshire spar. It is sometimes called *fluor-spar; fluor*, because it melts easily, and *spar*, on account of its appearance being similar to that of minerals which are called *spars*, or *sparry.* Fluor spar is found to consist of lime united to an acid, which is named *fluoric acid;* therefore the chemical name for fluor spar is *fluate of lime.*

But you wish to know, why we imagine the existence of a substance called fluorine. You remember that boracic acid has been found to consist of a base, called bo-

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Describe the mode of obtaining iodine?

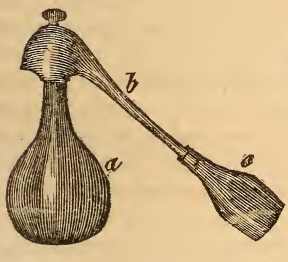
What imaginary substance do chemists class among the elements?

What is fluor-spar?

Why is fluorine supposed to have an existence?

ron, united to oxygen; and that carbonic acid is composed of a base, carbon, united to oxygen, and so of all the acids we have noticed; they all consist of a base united to an acidifying substance. Reasoning therefore from *analogy*, chemists have thought that fluoric acid must also be a compound, consisting of a base united to oxygen, or some other acidifyer; this imaginary base has received the name of fluorine, because it is thought, in some respects to resemble idoine, and some other substances ending in *ine*, which we shall soon examine. We shall not attempt to say any thing about this fluorine, which, like the hero of a novel, is but an imaginary thing. Fluoric acid has hitherto resisted all attempts to decompose it, so that, if fluorine does exist, it is so well satisfied with the companion to which it is united, that no temptations can induce it to separate.

Method of obtaining Fluoric Acid.



Experiment.—Fluoric acid is obtained in the state of a gas, from fluor spar, by means of elective affinity. For this purpose, sulphuric acid is poured upon pulverized fluor-spar. Heat is applied, and the fluoric acid gas immediately begins to ascend. The figure represents an apparatus for collecting this gas. It must be of silver, as glass would not answer, for reasons we shall soon mention. The fluor-spar and sulphuric acid are put into the flask *a*, the gas passes through the tube *b* into the receiver *c*.

Explanation.—Fluor-spar, or the fluate of lime, consists of lime and fluoric acid. Lime has a strong affinity for sulphuric acid and unites with it, while

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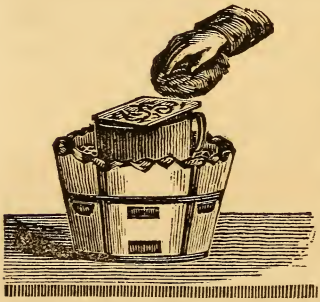
How is fluoric acid obtained?
Explain this process.

the fluoric acid, being set free, escapes. The substance remaining in the flask is now a *sulphate* of lime, while that in the receiver is fluoric acid in the state of a gas.

Properties of Fluoric Acid.

One of the most important properties of fluoric acid is its great affinity for a mineral called *silex*, which constitutes the gritty part of stones, and forms a considerable portion of glass. This acid dissolves or eats glass, by uniting with the silex; and this is the reason that glass vessels cannot be used for obtaining fluoric acid.



In the figure is a representation of an *etching* box, placed over a furnace of coals; some fluor-spar being pounded, is put into the box, and sulphuric acid added. As soon as the gas begins to rise, a piece of glass, having been previously coated over on one side, with beeswax, and written upon or sketched through the wax with a pin, is placed over the box, with the waxed side down. To prevent the wax from melting by the heat, a sponge wet in cold water is applied to the upper side of the glass. In a few seconds after the gas has begun to act, the glass may be removed. On scraping off the wax, the words written, or the picture sketched, will be found engraven upon the glass. The wax is put on, in order to protect the glass from the action of the acid, except where the engraving is to appear.

What are some of the most important properties of fluoric acid?

Describe the process of etching or engraving on glass.

The fluoric acid gas produces this effect on glass in consequence of acting upon a portion of the silex of which it is composed; united to this silex, it forms a new compound, called *silicated fluoric gas.*

The vapours of fluoric acid are very dangerous when brought to act upon any part of the body, and especially when inhaled into the lungs. One writer on Chemistry mentions that his assistant suffered severely, for several weeks, in consequence of the vapour of this acid acting upon his finger; and that six drops of the acid falling upon the back of a dog, in a spot where there was no hair, produced great agony and death in a few hours.

Bromine.

Bromine is a newly discovered element; the name is from the Greek *bromos*, signifying an unpleasant odour, a circumstance which marks this substance. It was discovered by a French chemist in making some experiments with the ley obtained from the ashes of sea-weed and other marine plants. It exists in sea water in the state of a *hydro bromic** acid united to magnesia. The process of collecting bromine, separate from its combinations, is long and difficult.

It is a *liquid* of a deep red or brown colour, much heavier than water; its weight in comparison to Hydrogen is 75. It is very *volatile*, that is, it has a tendency to pass into the state of a vapour; a drop or

* *Hydro* signifies in a moist state, or combined with hydrogen to form water.

Why does fluoric acid produce the effect on glass which takes place in the process just described?

What is the effect of fluoric acid upon the animal system?

What does the name bromine signify, and when and how was the substance which is so called discovered?

What are its properties?

two will fill a quart glass vessel with red vapours. It is very poisonous; its vapour supports combustion feebly but before a candle is extinguished in it, the flame, presents a singular appearance, being green at the bottom, and red at the top. Bromine does not change vegetable blues to red, therefore it is not an acid; but it bleaches them, and even destroys the colour of indigo.

Its chemical affinities are numerous; it forms acids with hydrogen and oxygen; it forms salts with alkalies which are called *bromates*, and combines with metals forming *bromides*.

You will perceive that bromine in some respects resembles iodine, in connexion with which, it is usually found. Like iodine it is attracted to the positive pole of the galvanic battery, and is therefore classed among the electro-negative substances, oxygen, iodine, fluorine and one which we have not yet examined, called *chlorine*.

Bromine is very rare and dear in this country. Two years ago, when Professor Silliman published the last volume of his 'Elements of Chemistry,' he says, 'I have just obtained from Paris, two vials, containing each, not more than a thimble full; the price was eight dollars.'

Does it readily unite with other substances?
In what respects does bromine resemble iodine?
Is it a common substance?

CHAPTER XVI.

Muriatic Acid. Chlorine.

THE last of the gases which we have to notice is called *chlorine.* We have deferred its examination, not because it was an unimportant substance, but because there is some dispute among chemists as to its being *an element*, and we did not wish to perplex you with arguments about this, while you were ignorant of the nature of substances which are more easily understood.

You have often been told, in the progress of your study, about *muriatic acid;* now according to the present opinion of most chemists, respecting the nature of chlorine, and according to the principles by which acids are named, muriatic acid ought to be called *hydro-chloric* acid, it being considered as a compound consisting of *hydrogen* and *chlorine*, but the name having been long established, it is not easy to alter it, although for the sake of greater uniformity and clearness, many scientific men would be glad to do it.

Muriatic Acid.

Before proceeding to treat of chlorine directly, we will consider the substance from which it is obtained: this is muriatic acid, or, as before remarked, more scientifically (though not so commonly) called, hydro-chloric acid.

Muriatic acid is so called from *muria*, the Latin name for sea salt, from which it is usually obtained.

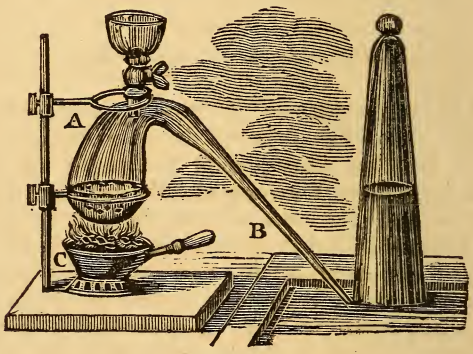
What gas is now to be considered?

What does muriatic acid consist of, and what is the most proper name for it?

From what substance is chlorine obtained?

Why is muriatic acid so named?

Liquid muriatic acid has long been known, but the discovery of its gas was not made till the latter part of the last century.



The figure represents a method of obtaining muriatic acid gas—at *A*, is a retort containing common salt; sulphuric acid in sufficient quantity is poured through the glass tunnel, and the stop cock turned in order to prevent any gas escaping in that direction. *B* shows the tube of the retort passing under a receiver filled with mercury and inverted over a trough of mercury. At *C* is the chaffing dish of hot coals to hasten the process that is going on in the retort.

Explanation.—Common salt is a *muriate of soda;* that is, it is composed of muriatic acid united to soda; the latter having a greater affinity for sulphuric acid, unites with it, forming *sulphate of soda*, and excludes the muriatic acid; this rises in the retort, and is conducted through the tube into the receiver filled with mercury; as fast as the gas rises, the mercury gives

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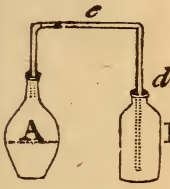
Has it been lately discovered?
Describe the process for obtaining muriatic acid.
How do you explain this process?

place; as the receiver now appears, it is about half filled with gas. You will recollect that such is the affinity of muriatic acid gas for water, that it cannot be collected through it like many of the other gases, as it unites with it and assumes the liquid state.



Muriatic acid is heavier than the common air; this is shown by collecting it, by means of an apparatus like that which is here represented. The bottle *A*, being filled with the substances which produce the gas, communicates with an empty receiver *B* by the tube *c*, as the gas passes over, it settles at the bottom of the vessel, and the air consequently rises until the whole space being filled with the gas, it begins to issue forth from the mouth at *d*—it may be known by its peculiar smell and the white vapour which it forms.

Properties of Muriatic Acid Gas.

It is colourless, of a sharp odour and extinguishes combustion. Its affinity for water is such, that it attracts it from the atmosphere, and forms white vapours. It turns vegetable blue colours red. It melts ice with great rapidity, and is strongly absorbed by water. It is fatal to animal life.

Liquid Muriatic Acid.

Every chemical laboratory ought to be furnished with liquid muriatic acid, as it is of importance in many experiments. It is obtained by saturating water with

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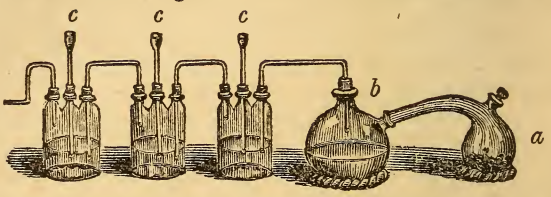
What experiment proves muriatic acid gas to be heavier than common air?

What are the properties of this gas?

How is liquid muriatic acid obtained?

the gas, as in the figure. This is called Woulfe's ap-



paratus from the name of the inventor.* The retort *a* contains common salt and sulphuric acid; the muriatic acid gas passes into the glass globe *b*, where it is washed from some sulphuric acid which is generally carried along with it—the gas then passes through the tube to the bottle next the globe, where it is received into water; when this water is saturated with the gas, it passes on through another tube to the next bottle, and thus the process is continued.—The number of bottles may be increased or diminished. The strait tubes *c*, *c*, *c*, are called safety tubes; they admit atmospheric air into each bottle when the gas ceases to come over from the retort, thus preventing a vacuum which might draw in the impure acid from the globe or first bottle.

Silliman observes, '*the sulphuric, the nitric, and the muriatic, are the three cardinal acids of Chemistry and the arts. We could effect very little in practical Chemistry without them.* Of the three, the sulphuric is the most useful, because besides its own numerous and important applications, it is the principal instrument in making the other two.'

Uses of Muriatic Acid.

Besides its many applications in assisting the chemist in his analysis of other substances, muriatic acid is of impor-

* For a further discription of Woulfe's Apparatus, see the author's Dictionary of Chemistry, articles 'Absorption,' and 'Apparatus.'

What does Silliman say of the importance of three of the acids?

tant use in medicine and in the arts. It is very useful in a sick room, by destroying disagreeable odours, and preventing contagion. A little common salt in an earthen vessel, placed over coals, requires only the addition of a small quantity of sulphuric acid, in order to obtain the muriatic acid gas, the fumes of which are powerful to destroy the effect of other gases; and all contagion is conveyed by means of bad air, or unwholesome gases. An instance of the power of muriatic acid gas as a disinfecting agent, is thus related by Professor Silliman. 'At Dijon, in France, there is a cathedral which in 1773, was from the corpses interred beneath it, so infected with putrid miasmata* that it had been deserted, after a number of unsuccessful attempts to remove them and purify the air by explosions, aromatics, &c. Application being made to Professor Morveau† for a remedy, he took a glass vessel, supported by one of cast iron, and placed it on a few live coals in the middle of the church. He then put into it six pounds of common salt, and two pounds of sulphuric acid, and hastily withdrew closing the doors after him. The muriatic acid gas soon filled the vast space and could be perceived even at the doors. At the end of twelve hours, the church was thrown open and ventilated.' Thus by means of chemical science, that vast and ancient church which otherwise must have been destroyed or given up to owls and bats, lizards and noxious reptiles, was purified and rendered a meet temple for the worship of God.

Muriatic acid forms many combinations with other substances. With nitric acid it forms a compound called *aqua regia*, from the Latin, signifying kingly water.

* *Miasma* is a Greek word, signifying noxious matter, or small particles which float in the air and produce diseases or bad smells. *Miasmata* is the plural of miasma.

† A distinguished French chemist, see Dictionary of Chemistry, page 21.

What are some of the uses of muriatic acid?

This name was given by the first chemists who were called *alchymists*, and whose great object was to change all metals into gold. *Nitro-muriatic acid*, or aqua regia, is the only liquid known which has power to dissolve gold. With alkalies, muriatic acid forms salts, called *muriates*, as common salt, which is usually called the muriate of soda, &c.; but which, according to late discoveries, is a *chloride* of sodium.—Muriatic acid is composed of 1 part chlorine, whose atom is called 36, united to 1 part hydrogen.

The number, therefore, which represents this acid is 37; this is called its *chemical equivalent.* You will remember that hydrogen is the unit, or 1, to which all other elements are compared, and you will observe that one atom of chlorine weighs 36, while one atom of hydrogen weighs only 1.

Chlorine, or Oxmuriatic acid.

Although this chapter is already a long one, we must ask your patience till we have examined chlorine, a description of which, although a simple substance as it is obtained from muriatic acid, we omitted till we had considered the latter. It was in the year 1774, that Scheele, a Swedish chemist, being engaged in some experiments with the oxide of manganese, added to it liquid muriatic acid, when a gas, of a yellowish green colour, and a very strong and disagreeable smell, was observed to issue forth from the combination. Since that period, this gas and its compounds have been considered as among the most interesting subjects of study in the whole range of chemical science.

It was at first thought, that, as the oxide of manganese contained a large portion of oxygen, a portion of the

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What are some of the combinations formed by the union of muriatic acid with other substances?

What is the chemical equivalent for muriatic acid?

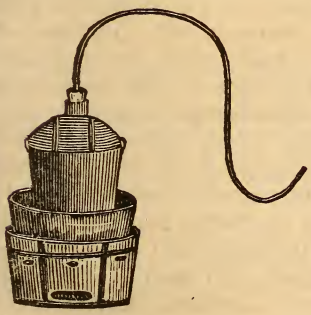
When and by whom was chlorine discovered?

latter, uniting to the muriatic acid gas, produced the newly discovered gas, and on this supposition it was named *oxmuriatic* acid.

As chemists attempted to decompose it, they found it resisted all the agents which they could employ for this purpose; they, therefore, began to believe that it was a simple substance, and gave it the new and independent name, Chlorine, from the Greek *kloros*, green, on account of its peculiar colour.

Method of obtaining Chlorine gas.

Chlorine may be obtained with muriatic acid and the oxide of manganese, or by the following process, which is described in Silliman's Chemistry: common salt, oxide of manganese, and sulphuric acid are put into a pot of sheet lead, such as you see in the figure, and furnished with a leaden tube which is fitted into the cork. The pot is then placed in a tin pan containing hot water, and standing over a furnace. The gas must be collected in vessels filled with warm water; the water if cold will absorb the gas.



Explanation.—How is chlorine obtained from the substances which were put together in the leaden vessel? This question those will ask who desire to understand

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Why was this at first called oxymuriatic acid?
Why was its name afterwards changed to chlorine?
How may chlorine be obtained?
Can you explain the rationale of the process by which chlorine is liberated from salt with the help of the oxide of manganese and sulphuric acid?

the causes of things; we will therefore tell you what Chemists now believe to be the *rationale* * of this process.

They think that chlorine combined with hydrogen, exists in muriatic acid, forming hydro-chloric acid, which you will recollect we mentioned as being, now, the scientific name for muriatic acid. Now in order to obtain the chlorine, it is only necessary that the hydrogen shall be separated from the muriatic acid which the salt furnishes; this is supposed to be done by means of the oxygen which comes from the oxide of manganese, and which is pressed out by the union of the latter with the *sulphuric acid*, forming a *sulphate of manganese.* The oxygen furnished by the manganese, uniting to the hydrogen of the muriatic acid, forms water. One portion of the sulphuric acid unites with the soda of the common salt, (muriate of soda,) forming the sulphate of soda, while the muriatic acid being set free gives its hydrogen to the oxygen of the manganese, and the new chlorine gas appears.

Liquid chlorine may be obtained by putting pounded red lead, (oxide of lead) and common salt into a bottle containing water, to this mixture is added sulphuric acid; after agitating the contents of the bottle, and plunging it into a cold water to promote the absorption of the gas by the water in the bottle, the liquid will assume that yellowish green colour peculiar to chlorine. Any piece of calico, or other coloured substance if introduced into this bottle of liquid chlorine, will soon appear colourless.

Properties of Chlorine Gas.

The colour is greenish yellow; the smell suffocating and offensive: it is very dangerous to the lungs, its ef-

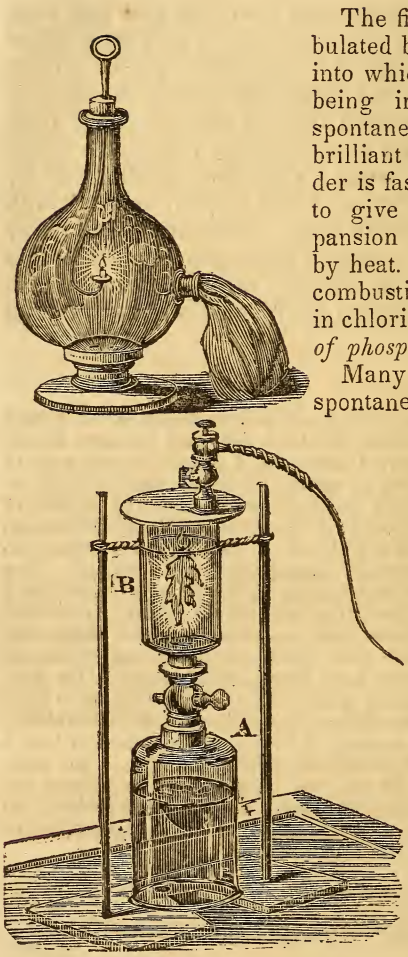
* Pronounced ra-shun-a-le, signifying the reasons for any process. This is a term so common in Chemistry that the author would not think of defining it, if this were not a work for '*Beginners.*'

How may liquid chlorine be obtained?

fects sometimes appearing long after the gas has been inhaled. * One of its most remarkable properties is that of destroying all animal and vegetable colours; on this account, it is of great use in manufactories, where it is used in a combination with lime, called *chloride of lime.* Chlorine is a supporter of combustion, though far inferior to oxygen in this respect; a burning candle, held by a wire, in a vial of this gas burns a short time, though dimly, and with a reddish flame. Phosphorus and many other substances are inflamed spontaneously in chlorine gas; on account of this property, the salts made with it, are used in the composition of fire crackers, rockets, and other fire works.

* I cannot refrain from giving here a little notice of two young men, who have fallen victims to their zeal and boldness in the cause of science, especially, Chemistry; I allude to two sons of Professor Amos Eaton, one of whom, Hezekiah, died recently at Lexington, Ky. filling with distinguished honour the station of assistant professor of Chemistry in Transylvania University. His brother Dwight, died at Troy, N. Y. several years before, too young to have made himself extensively known abroad. But those who witnessed the enthusiasm, and courage of these young men, for making the boldest experiments, the intuitive readiness with which they seized upon facts, and the clearness of their judgment, to make deductions from these, can never cease to lament that they should so often have exposed themselves to the deleterious influences of deadly gases, which, operating upon their physical system like a slow poison, undermined their constitutions, and thus deprived their country of those who promised to take a high rank among the intellectual men of the age. To their father, the veteran whose life has been devoted to science, she owes the sacrifice of these two sons, the glory and pride of his declining years, while his own impaired health shows that he has not withheld the sacrifice of himself.

What are the most important properties of chlorine gas?



The figure represents a tubulated bottle of chlorine gas into which some phosphorus being introduced, it burns spontaneously, and throws off brilliant jets of fire. A bladder is fastened at the tubulure to give room for the expansion of the chlorine gas by heat. The product of this combustion of phosphorus in chlorine, is called *chloride of phosphorus.*

Many of the metals burn spontaneously in chlorine—The bell glass *B*, represents the combustion of gold leaf in this gas. The lower bell glass *A*, was first filled with chlorine over the pneumatic cistern; the upper bell glass was exhausted of air by means of an air pump, and the pipe which is connected with the apparatus. On turning the stop-cock between the two bell glasses, the gas from the lower one rushed up to fill the vacuum, and the gold leaf was immediately inflamed, and burned with great brilliancy forming *chloride of gold.*

How is the chloride of phosphorus formed?
How is the process for burning gold leaf in chlorine described?

CHAPTER XVII.

We have now completed our view of the *ponderable elements* which are not metallic. You will reccollect that we first noticed the imponderables, caloric, light, electricity, and magnetism, and then proceeded to the consideration of those elements which have definite weight, and are therefore called ponderable.

The ponderable elements consist of two classes, *supporters of combustion, and combustibles.*

The supporters of combustion are oxygen, chlorine, iodine, fluorine and bromine; oxygen, by way of distinction is called '*the great supporter of combustion.*'

The *combustibles not metallic,* are Hydrogen, Nitrogen, * Sulphur, Phosphorus, Selenium, Carbon and Boron.

We did not follow the arrangement above given of combustible and non-combustible substances in our view of these substances, because we wished first to examine Oxygen and Nitrogen to show the constituents of the atmosphere, and then we examined Hydrogen in order that we might illustrate the composition of water. Chlo-

* Nitrogen is combustible in the sense in which Chemists consider combustion to be the union of a substance with oxygen; but it does not take fire on being brought in contact with a burning substance, and is not therefore combustible in the common understanding of the term.

What elements have we now in this work considered?
Of what two classes do the ponderable elements consist?
Which are *supporters of combustion?*
Which are *non-metallic combustibles?*
Why were not these classes observed in the previous arrangements of the subjects of this work?

rine was considered last, because the process for obtaining it, is somewhat complicated and might embarrass a pupil in the commencement of his studies.

With that part of the alphabet of Chemistry which we have examined, are formed either amongst themselves, or in connection with other substances, all of the most important combinations in nature. We shall now consider some of these combinations of non-metallic substances with each other, which we have hitherto omitted, that your attention might be chiefly given to the elements themselves.

AMMONIA.

A compound of Nitrogen and Hydrogen.

Ammonia* consists of one part Nitrogen, which is represented by the number 14, and of three parts Hydrogen which are called 3 ; therefore as 14 and 3 are 17, the latter number represents Ammonia, or is called its *chemical* equivalent.

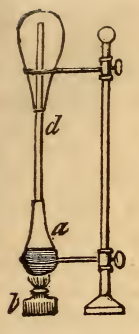
Hartshorn (sometimes called *volatile* salts, and *volatile* spirits) is an article in very common use. In powder it is used in *smelling bottles*, and in a liquid state it is used for medicine. Hartshorn is so called because it is obtained by burning the horns of harts or deer. Hartshorn is a *carbonate of ammonia.*

* The name ammonia, is by some, supposed to be derived from *amnos*, sand, because it was first procured from the sandy country Lybia, by others it is thought to be named from the temple of Jupiter ammon.

What is said of the importance of the elements which have been examined ?

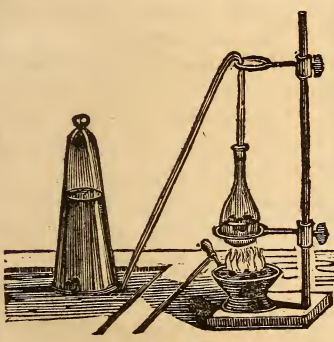
What does ammonia consist of, and by what number is it represented ?

What is hartshorn, how obtained, and how used ?



By applying heat to the liquid ammonia, a gas of a very powerful nature is disengaged; *a*, is the vessel containing the liquid ammonia, *b*, the lamp, *c*, the receiver, and *d*, the tube which connects the receiver to the flask. The gas of ammonia, being lighter than the air, rises, and takes its place in the upper vessel.

The following figure represents another mode of obtaining this gas; the receiver being filled with mercury and inverted over a mercurial cistern. The retort, instead of liquid ammonia, contains powdered muriate of ammonia, and slacked quick lime. The muriatic acid leaves the ammonia to unite with the lime, and the ammonia is set free. This experiment shows the action of two solids in producing elective affinity.



Muriate of ammonia is known in the shops of druggists as *sal-ammoniac*, which means salt of ammonia.

Ammonia cannot be produced by synthesis or mixing hydrogen and nitrogen gases; but it seems necessary that they should be brought in contact, at the instant they pass from other combinations, in order to unite in the proportions necessary to form this substance.

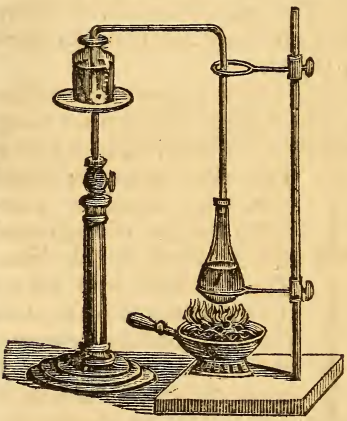
How may the gas called ammonia be obtained from liquid ammonia?

How may it be obtained from muriate of ammonia and lime?

What is the common name of muriate of ammonia?

Can ammonia be produced by a mixture of the gases which compose it?

During the decomposition of animal substances both hydrogen and nitrogen are given off, these unite, and form ammonia; thus from putrid and offensive matter arises a gas the smell of which is reviving, and a preventive to putrefaction.



The figure shows a method of obtaining liquid ammonia. The retort contains the muriate of ammonia and lime; the tube conducts the gas into a bottle containing cold water, which absorbs it rapidly.

Ammonia is an alkali;—that is, it changes vegetable red colours, blue; changes blue colours green, and yellow colours brown; it is *caustic* to the taste; it combines with acids to form salts, and with oils to form soaps.

The volatile liniment, used for burns and sore throats, is composed of ammonia and sweet oil.

Combinations of carbon with simple bodies are called *carburets*;—the most important of these is *carburetted hydrogen*, one kind of which forms the gas which is used for lighting the streets of cities.

Those of you who have walked out of an evening in the principal streets of New York, or of some other large city, cannot fail to have noticed the beautiful and brilliant lights which illuminate the streets, shops, and public

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What gas is produced during the decomposition of animal substances?

How is liquid ammonia produced?

Why is ammonia considered as an alkali?

With what does it combine to form volatile liniment?

places; sometimes issuing forth in many small jets of flame from elegant chandeliers of curious construction, and at others appearing in one large effulgent blaze. These lights burn without any wick; they are caused by the combustion of gas. You will recollect that carbon and hydrogen are both highly combustible substances; we should naturally infer that when united, they would burn with force and brilliancy.

There are several varieties of carburetted hydrogen; that which is used for gas lights is either obtained from coal or oil. Coal, we have found, is chiefly composed of carbon; that which is used for gas lights is a damp kind, called *pit coal*, which is dug from mines. The water in the coal furnishes the hydrogen. Oil is composed principally of carbon and hydrogen; the gas obtained from it is much purer than the *coal gas*.

Coal Gas.

An apparatus for furnishing coal gas lights consists of a large iron vessel which contains the coal; this vessel is placed over a furnace, and the gas which rises is made to pass through a tube into a vessel of cold water, called a *condenser*, which cleanses it of many impurities; it is then conducted through a mixture of quick lime and water, called the *purifier*, which absorbs the carbonic acid and sulphuretted hydrogen; it is then transmitted into a *gasometer*, or vessel prepared for the reception of the gas, and furnished with tubes which may be made to pass in any direction which is required. In some large gas manufactories, the gasometers are twenty feet high and thirty in diameter. They are made of sheet

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What are carburets?

What lights are used in some cities for lighting the streets, shops, &c.?

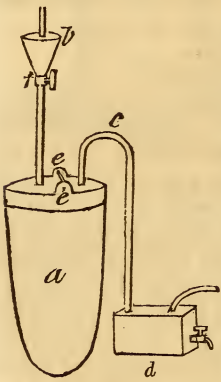
From what substances is the carburetted hydrogen used for gas lights commonly obtained?

How is coal gas manufactured and conveyed to different places?

iron—from this great fountain of gas, tubes placed under ground proceed to the different streets, and buildings where it is used, in the same manner as water is conducted from one place to another through hollow cylinders placed under ground.

Oil Gas.

Oil gas is obtained chiefly by the distillation of whale oil, which is made to drop slowly into a vessel containing pieces of red hot bricks or coal; the apparatus in other respects resembles that for obtaining coal gas. The oil gas is considered the most pure, and brilliant; it is the cheapest, except in places very near to coal mines, where the coal is sold very cheap.



The vessel *a* is supposed to be made of cast iron; in its cover are two openings, one of which has fitted to it a small copper tube having a funnel shaped vessel *b*, to receive the oil; to the other opening is fitted a bent iron tube *c* which communicates with a copper condensing vessel *d*; from the top of this issues a lead pipe which may be made to communicate with a gas holder. In order to obtain oil gas, pieces of brick are put into the vessel *a* which is placed over a furnace to be heated; when it is heated to redness, oil is poured into the funnel shaped vessel and the stop cock at *f* being turned it falls drop by drop upon the bricks; the gas which is produced passes into the condenser *d*.

Spirits of turpentine and common resin may be used in the manufacture of gas lights. If you have ever no-

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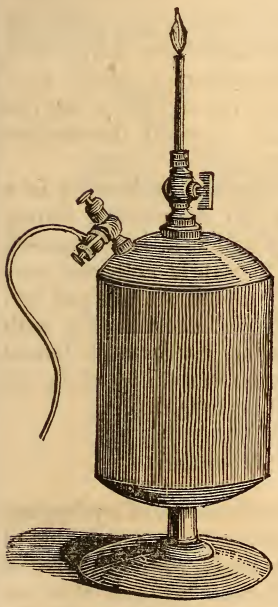
What is said of oil gas, and the mode of obtaining it?

Describe the apparatus illustrating the manufacture of oil gas.

What other substances besides coal and oil may be used for gas lights?

ticed the brilliant light made by the burning of a pine knot, you can readily believe that turpentine, which is the substance that burns so brightly, might afford a gas that would be very luminous.



The figure shows a *portable* gas light, or a copper vessel, which being filled with olefiant gas can be conveyed from one place to another. The flexible pipe serves the purpose of conveying the gas into the receiver, after it has been exhausted of air; the stop cock near the insertion of the pipe is then turned to prevent the escape of the gas, and the one near the perpendicular tube is turned to admit the gas through the orifice, where after being inflamed, it continues to burn till the whole is consumed.

Bi-Carburetted Hydrogen, or Olefiant Gas.

The gas used for lights is *bi*-carburetted hydrogen;* that is, 2 atoms of carbon united to 2 atoms of hydrogen —carbon being represented by 6, we have 12 of carbon to 2 hydrogen (an atom of hydrogen being 1); so that 14 is the equivalent of this gas.

* From the Greek *bis*, two, meaning *twice* carburetted hydrogen.

What are the proportions of carbon and hydrogen in bi-carburetted hydrogen, and why is it so called?

Bi-carburetted hydrogen is called *olefiant* gas, because with chlorine it forms an oily substance; it is also called *heavy* carburetted hydrogen, on account of its specific gravity being greater than that of the other combinations of carbon and hydrogen.

The bi-carburetted hydrogen or olefiant gas gives the most luminous flame of all gases—hydrogen burns with a pale light, simple carburetted hydrogen which contains but one atom of carbon burns more vividly, but the additional atom of carbon which exists in the olefiant gas renders it still more brilliant.

This gas is obtained for experiments, by heating in a retort, alcohol with sulphuric acid; the alcohol burns, and the carbon and hydrogen of which it is composed, unite and form the olefiant gas, which is collected over water. If a small quantity of pounded coal be put into the bowl of a tobacco pipe, covered over the top with clay and then placed in burning coals, a stream of olefiant gas will issue forth, which may be known by applying to it a lighted taper, when it will be inflamed.

Light Carburetted Hydrogen.

We have here but 1 atom of carbon to 2 of hydrogen; therefore, as 6 the atom of the one, to 2 the two atoms of the other, make 8, this number is the representative of carburetted hydrogen—the difference between this gas and the bi-carburetted hydrogen, consists then, in the different proportion of carbon which exists in them.

The specific gravity of this gas is less than that of the *bi-carburet*, on account of its containing less carbon.

Why is it also called olefiant gas?
Which is the most luminous of the gases, and why is it so?
How may olefiant gas be obtained for experiments?
What are the proportions of hydrogen and carbon in light carburetted hydrogen?
Why is its specific gravity less than that of the bi-carburet?

Carburetted Hydrogen.

It is called *inflammable air*, and sometimes the *inflammable air of marshes*, because it is formed in low, damp grounds, during the decomposition of animal substances. It may be collected over muddy and stagnant waters, by stirring the mud beneath a receiver; as ap-

pears in the cut, which represents a vessel suspended in the water of a pond, and the gas rising as the mud at the bottom is disturbed.

Coal mines, which furnish in abundance, the elements of carburetted hydrogen, are often scenes of fatal accidents to the workmen engaged in them. Ascending from the coal beds, the gas remains floating in the air, and the instant it comes in contact with a flame, takes fire and explodes with great violence.

In England there are many coal mines; whole villages of people attend to the mining business as their only way of getting a support; some families live

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Why is it sometimes called the inflammable air of marshes?
In what way does this gas cause accidents in coal mines?
Why did this gas become a terror to the miners of England?

wholly in the mines; and it is said people are often born in them, and live to old age without ever leaving them. It was a dreadful thing to these poor people to feel in constant dread of the *wild-fire damp*, as they called this gas—for they cannot work without a light, and their lamp must every moment expose them to this destruction.

Many dreadful accidents having occurred, in some instances destroying nearly a hundred workmen at a time. Sir Humphrey Davy, who was known as a man of much science, was applied to, with the hope that he might discover some means by which the miner could pursue his employment, and thus furnish the country with fuel, without the danger of such dreadful accidents. Sir Humphrey listened to the application with deep interest; he immediately took a journey to the coal region; he went into the mines, conversed with the miners, and obtained from them all the information they could give, respecting the nature of this *fire damp*. He then collected the gas, and examined its properties by various experiments.

He discovered one fact with regard to this substance, which suggested to him a way of preventing its explosion. He found that even red hot iron, in contact with the gas, did not set it on fire, while the smallest point of flame would cause an immediate explosion; this brought to his mind the fact that another chemist, Dr. Wollaston, had discovered, 'that an explosive mixture cannot be kindled in a glass tube so narrow as one seventh of an inch

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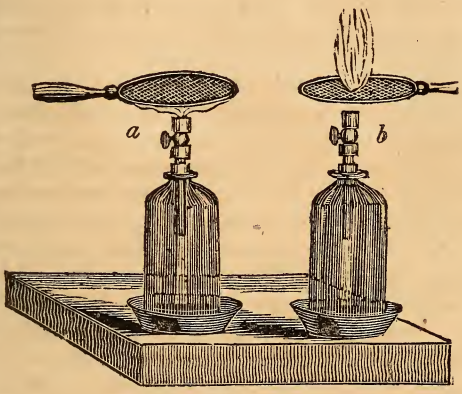
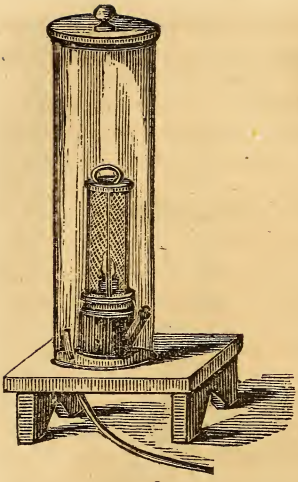
What is said of the application made to Sir Humphrey Davy, and of his attention to it?

What suggested to him the idea of his safety lamp?

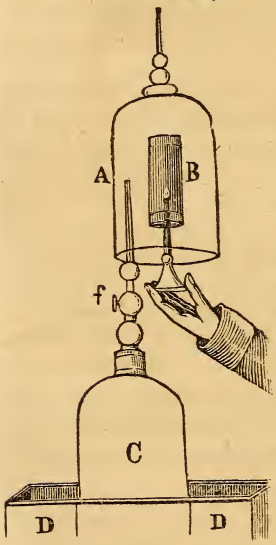
in diameter.' This fact he proved by the experiment represented in the figure. He procured two vessels of the



light carburetted hydrogen gas, or fire-damp, each fitted with a tube and stop-cock, and as the gas issued forth at each orifice he set fire to it; when it was burning he held over one orifice *a*, a piece of fine wire gauze or net-work; but, as you see in the figure, the blaze, instead of passing through it, was turned away. He set fire to the gas of the other orifice *b*, *above* the wire gauze, and although it burnt freely, the flame had no effect upon the gas below. The net-work of wire is made of a vast number of very small *tubes* connected together. Sir Humphrey Davy having proved that such a net-work would secure the flame from the external air, then went to work and constructed a lamp, which is known throughout the civilized world as *Davy's Safety Lamp.*



This is the safety lamp which you see in the figure. The oil and wick are in the lower part, which is fed with oil by the spout on the side. The flame is surrounded by a cylinder or cage of wire gauze, so fine that in every square inch there are at least, 625 apertures. At the top, where the greatest heat exists the wire gauze is double. There are conveniences for raising the wick, and replenishing the oil, without opening the lamp and thus exposing the flame to the external air.



This figure represents a large bell glass A, suspended over a jar C, filled with carburetted hydrogen, and standing over water of the pneumatic cistern D D. A safety lamp B is held under the bell glass; now by turning a stop-cock, fitted to the tube of the jar C which contains the gas, the *inflammable air* is allowed to pass up into the bell glass A and mingle with the common air which it contains; a certain portion of which renders the fire-damp more explosive than when unmixed. The flame of the lamp will change its appearance and exhibit a green or delicate blue colour,

Describe the safety lamp.

What experiment proves perfectly that the safety lamp is secure even when burning in an atmosphere of inflammable air?

and finally be extinguished; but it will not set fire to the external gas, which would be the case, should the smallest portion of flame come in contact with it.

From the little sketch we have given of the method pursued by Sir Humphrey Davy in his invention of the safety lamp, the young may see that knowledge does not, of itself, come into the mind, without labour. When a person begins to search into the nature of things, then it is that new ideas seem to arise in the mind—one experiment suggests another, and so on until the process often ends in the discovery of some new principle, or some new application of principles before known. In this way oxygen gas, and all the other gases, so important in chemical science, were discovered; and to such a process of inquiry we owe, not only the invention of the safety lamp, which gives security to thousands of labourers, as they go forth to their daily toil, but that of the steam engine, the printing press, and a vast number of improvements which tend to the comfort of life and promote the good of society.

CHAPTER XVIII.

Sulphuretted Hydrogen. Cyanogen. Prussic Acid.

SULPHURETTED HYDROGEN.

Compound of Sulphur and Hydrogen.

By an union of one atom of sulphur represented by the number 16, and one atom of hydrogen, represented

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In what way have most important discoveries among men been made? What is sulphuretted hydrogen?

by 1, a gas is produced called *Sulphuretted Hydrogen*, of which the chemical equivalent is 17; or, this is the sum of the two elements when added together.

The termination *uret* is applied to combinations of simple combustible, non-metallic substances with each other, and with the metals, alkalies, and earths; thus we have sulphuret of phosphorus, sulphuret of iron, phosphoret of lime, &c. But when the compound is gaseous, this is signified by the termination *uretted*, as we have just seen in the combinations of carbon and hydrogen, called carburetted hydrogen.

Modes of obtaining Sulphuretted Hydrogen.

Sulphuretted hydrogen is obtained by heating sulphur in connexion with hydrogen gas, as represented in the figure; the sulphur or brimstone is contained in the lower vessel, and the upper one is filled with hydrogen gas, which, from its specific levity keeps its place; as heat is applied, the sulphur or becomes a vapour, rises and unites with the hydrogen; thus forming sulphuretted hydrogen.

The same gas may also be obtained by heating sulphuric acid and the *sulphuret of iron*, (a combination of sulphur and iron). This is an instance of double elective affinity; the oxygen of the water of the liquid sulphuric acid, unites to the iron of the sulphuret, and sets the sulphur free; while the hydrogen of the water, being at liberty, unites with the sulphur, and forms sulphuretted hydrogen.

How are the terminations *uret* and *uretted* applied?

How is sulphuretted hydrogen obtained?

By what process is sulphuretted hydrogen obtained from sulphuric acid and the sulphuret of iron?

This is one of the most offensive of all the gases; it is not only highly disagreeable in its odour, which resembles that of bad eggs, but is very destructive to animal life; when pure, it kills almost instantly; and is very noxious, even when mingled with a large proportion of common air.

This gas is formed in nature in various places, particularly in cities, about wharves and in sinks where filth is suffered to accumulate. It exists in the atmosphere around sulphurous springs.

One property of this gas renders it of much importance to the world, viz; its power as a test to show the existence of poisonous substances—many of the most active poisons have a metallic basis—sulphuretted hydrogen has such an affinity for metals that it unites with them, and, by a change of colour, indicates their existence, where it otherwise might not be suspected. Thus arsenic, one of the most deadly poisons, may be detected by a yellow precipitate, and mercury by a black precipitate with sulphuretted hydrogen.

White lead (carbonate of lead) becomes black when exposed to sulphuretted hydrogen gas; and bismuth, another metal, becomes a dark brown—both these substances are used as the basis of the paints or cosmetics, which in some countries are used by females, under the mistaken idea of improving their complexions; bismuth is manufactured into a brilliant, white powder, sold under the name of *pearl-powder*. It would be a very unpleasant circumstance to a beautiful, painted lady, walking near a sulphur spring, or other place where the atmosphere contained some portion of sulphuretted hydrogen, to have her colour suddenly changed to that of a tawny

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What are some of its properties?
Does it exist in nature?
What important property does this gas possess?
To what accident are persons exposed who use such cosmetics as pearl-powder, white paint, &c.?

mulatto; but this is a risk that must always be incurred by those who use cosmetics prepared from mineral substances.

You have probably observed that a silver spoon, after being put into a boiled egg, becomes blackened—this is the effect of sulphuretted hydrogen—the yolk of eggs contains sulphur, the watery part contain hydrogen; when heated in cooking the two elements unite.

There is a combination called *bi-sulphuretted* hydrogen, in which two atoms of sulphur unite to one of hydrogen.

CYANOGEN.

Compound of Nitrogen and Carbon.

The word cyanogen is derived from the Greek *kuanos* blue, and *gennao* to produce, signifying the producer of blue. This substance gives its colour to the paint called *prussian blue.*

Prussian blue was discovered at Berlin, in Prussia, in the year 1704, and was then supposed to consist of an acid called *prussic* acid, united to iron;—by chemists prussian blue was for more than a hundred years considered as a *prussiate of iron.* The discovery of cyanogen, by one of the French chemists, a few years since, has wholly altered the names of the substances with which it combines.

It is obtained from a substance now called the *cyanuret* or *cyanide* of mercury, (formerly prussiate of mercury,) which on being heated in a small glass retort, gives off the cyanogen gas.

This is found to consist of 2 parts of carbon 12, and 1 part of nitrogen 14—thus the representative number of

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Why does a silver spoon become blackened in boiled eggs?
What is bi-sulphuretted hydrogen?
Why is cyanogen thus named?
What was prussian blue when first discovered supposed to consist of?
How is cyanogen obtained?

cyanogen is 26. Cyanogen, therefore, is not a simple element, though it forms combinations with other substances, much in the same manner as our chemical alphabet, oxygen, nitrogen, &c.

It combines with oxygen to form *cyanic* and *cyanous* acids, and another acid called *fulminic.**

Prussic acid—hydro-cyanic acid.

The acid which was obtained from prussian blue was at first called *prussic acid*;—as it is now known to be a combination of hydrogen and cyanogen, its more scientific name is *hydro-cyanic acid.*

This is an extremely poisonous substance; it kills small animals instantly—a single drop of it falling upon the arm of a German chemist, is said to have destroyed his life. Silliman relates that a medicinal preparation of this acid, which he had received from Paris, happening to get spilled upon the floor, although it was immediately covered and removed, produced alarming effects upon those present, such as fainting, loss of pulse, &c. which continued for several days.

Prussic acid exists in some vegetables, as the leaves and blossoms of the peach, and the kernels of the fruit, of the laurel and almond.

It is used in medicine but much diluted. So powerful an agent as this, should never be used at all but by a person of great science and experience.

* From *fulminate* to thunder; this acid forms explosive mixtures when combined with some of the metals.

Is cyanogen a simple substance?
Does cyanogen combine with oxygen?
What is the scientific name for prussic acid?
What are the properties of this acid?
Does it exist in nature?
What is said of its use in medicine?

Prussic acid, combined with iron, forms prussian blue, which is scientifically called *hydro-ferro cyanate of iron.**

Prussic acid is remarkable for its tendency to decomposition, as its elements seem so feebly united that they separate spontaneously. These elements, you will recollect, are three, nitrogen, carbon, and hydrogen.

No oxygen exists in this acid. It has neither an acid taste, nor does it turn blue vegetables red; but it is called an acid, because it combines with alkalies to form salts, which are termed *hydro-cyanates* or *prussiates.*

Cyanogen, you will recollect, is represented in Chemistry by the number 26,—one part of hydrogen, whose atom is 1 being added, gives 27 as the representative number of hydro-cyanic or prussic acid.

Cyanogen is a substance about which much might be said, but in a Chemistry for Beginners it is not to be expected that the different subjects named will be thoroughly investigated. It is the object of this book to give young persons a taste for the science, so that they can understand more extensive works, and especially to direct their attention towards the Great Volume of Nature of which God is the Author.

We find in pursuing our researches in Chemistry, how He has distributed around us the most deadly elements, as if to show that while He holds in his hand powers that would instantly destroy us, He has been

* *Hydro* from hydrogen, *ferro* from the Latin *ferrum*, iron. For a particular account of the discovery of prussian blue, and the manner of obtaining it, see Dictionary of Chemistry, p. 122.

What is the scientific name of prussian blue?

What are the elements which form prussic acid, and are they easily separated?

Why is this substance called an acid?

What is the representative number of prussic acid?

What remark is made respecting the object of this book?

What do we find in pursuing our chemical researches with respect to the creations of God?

pleased so to arrange and temper them, as to render them harmless or conducive to our service and comfort.

We have, in the progress of our work, concluded our examination of the *imponderable* elements, of all the *non-metallic*, ponderable elements; we shall, in our next chapter, commence with a new class of simple substances.

CHAPTER XIX.

Metalloids. Alkaline Metals.

ALKALINE METALS,—*Potassium, Sodium, Calcium, &c.*

We shall now, for a time, be occupied with a class of elements called *metalloids;* the termination *oids* is from the Greek, and signifies like or similar to. The word *metalloids* means, similar to metals.

The metalloids are in the strictest sense of the word metals; but they differ from the proper metals in their great affinity for oxygen, which circumstance renders it difficult either to obtain or preserve them in a state of purity; they differ greatly from the metals in their specific gravity. It is but recently, that they have been known to exist; the substances from which they are obtained, having been considered as simple, until late discoveries have proved them to be compound.

What subjects have now been considered?
What is understood by the term metalloids?
How do the metalloids differ from the proper metals?

Potash, soda, and lime were formerly classed as pure alkalies, but they are now known to be *oxides of metals.*

POTASH.

Combination of Potassium and Oxygen.

The potash of commerce is obtained by evaporating the ley of wood ashes and that of other vegetables. It was formerly called vegetable alkali. The name potash was given because the ley was boiled down in pots.

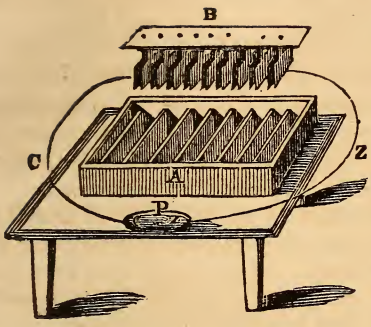
Potash was known to the ancients. The Romans in the days of Julius Cæsar, are said to have used soap made of ashes and tallow; and at Pompeii, which was buried by the eruption of Mount Vesuvius, 79 years after Christ, a soap-boiler's shop has been discovered, which contained soap that appeared to be of the same nature as our common soap, and which, although it must have been made more than seventeen hundred years, was perfectly preserved.

The ley that is obtained from the common wood ashes, and used in families for making soap, is a very impure solution of potash; as it usually contains more or less carbonic acid, quick lime is thrown into it, to which the acid unites, forming a carbonate of lime, and leaving the potash to act upon the grease.

Potash, in its purest state, is not an *element*, but an *oxide* of a metal called *potassium.*

Sir Humphrey Davy, in 1807, discovered the compound nature of potash. He subjected this alkali to the action of a powerful galvanic battery; it melted, oxygen appeared at the positive pole, and some metallic globules at the negative pole.

What are potash, soda, and lime?
How is potash obtained, and why is it so called?
Has it been long known and used?
Why is lime used in making soap?
Is potash an element or a compound?
How did Sir Humphrey Davy discover the compound nature of potash?



The figure represents a galvanic battery; A is the wooden trough, having partitions, the spaces between which are filled with weak brine or with water, containing a small portion of sulphuric or some other acid. The plates B which are alternately of zinc and copper, being shut down into the cells the galvanic action commences, or the opposite electricities are disengaged. Z represents the zinc or positive pole, being connected with a zinc plate; and C the copper or negative pole, being connected with a copper plate. The substance to be acted upon is placed in contact with the two poles;—if it is a compound body its elements will go to the different poles. As in the oxide of a metal, the oxygen will always go to the positive pole, and the metal to the negative. We will now suppose Sir Humphrey Davy attempting to learn the nature of potash—he brings a piece of dry, solid potash, places it upon a plate of platina within the galvanic circle (see P)—the potash begins to melt, and soon vanishes while oxygen appears at the positive pole Z, and little metallic drops at the negative pole C. When he saw this, the philosopher knew that he had made a grand discovery, which would greatly change the science of Chemistry, and be followed by many other discoveries.

This indeed was the case, for as soon as other chemists knew of Davy's discovery, they began to make new

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Describe the figure and the manner in which the decomposition of potash may be effected.

What effect had Davy's discovery upon the science?

experiments; and it was but a short time before several alkalies, hitherto considered as elements, were proved to be compounds, among these were soda and lime.

Potassium has such an affinity for oxygen, that in the air or in water, it combines with it; for this reason, it is preserved by chemists, in an oily substance, called naptha. It is on account of this affinity for oxygen, that potassium is found highly useful in decomposing other substances, by combining with their oxygen.

The union of potassium with oxygen, forms potash; thus the compound nature of this substance is proved by synthesis as well as analysis.

Potash is an *oxide* of potassium. Pearlash is a *carbonate of potash.* Saltpetre is a *nitrate of potash.*

Pure potash dissolved in water is a *hydrate of potash.*

Potassium does not exist in nature, except in a state of combination; this you will at once perceive must be the case, as it takes oxygen from both air and water, and becomes potash.

Potash is a powerful alkali, and therefore has a strong tendency to unite with acids; the effect of this union is a neutral salt, which exhibits neither acid nor alkaline properties. If the colour of a carpet, or a garment is changed by an acid, a solution of potash, by neutralizing the acid, would remove the stain. Pearlash is better for this purpose, as pure potash is very caustic, and has such an affinity for animal substances as to destroy them. Woollen cloths are made of an animal substance.

Besides its use in making soap, potash is employed

Why cannot potassium be preserved in water or in the open air?

What substance is formed by the union of potassium with oxygen?

What are the chemical terms for potash, pearlash, and salt petre?

What is a hydrate of potash?

Does potassium exist pure in nature?

What is the effect of the union of potash with acids, and how may a knowledge of this effect be turned to an economical purpose?

in the manufacture of glass, by melting it with sand; under the form of pearlash, it is much used by the housekeeper to make gingerbread and other cakes light; it is often called *sal-æratus.*

Potassium is soft like wax, and has a beautiful metallic lustre, but it is immediately covered with a coat of potash, if exposed to the air; if thrown upon water it floats and burns on its surface, so rapidly does it unite with oxygen.

The specific gravity of potash is 1.700, that of potassium 0.805, or less than water.

The weight of potassium compared with hydrogen is 40; potash consists of 1 atom of potassium and 1 of oxygen, 8; it is, therefore, represented by 48.

SODA.

Compound of Sodium and Oxygen.

You will readily comprehend, from what has been said respecting the nature of potash, that soda, another powerful alkali, is also a compound substance. This is the *oxide of sodium.*

The soda in common use is not, however, the pure oxide of sodium, but a carbonate of soda. It was formerly called barilla.

By an Arabian chemist of the ninth century, soda was described, but considered as the same thing with potash. The difference between them is in many respects great. Soda is obtained by the burning of salt-water plants; the ashes are leached and the ley is then evaporated.

What are some of the uses to which potash is applied?
What are some of the properties of potassium?
What is the specific gravity of both potash and potassium?
What is the weight of an atom of potassium and the representative number of potash?
What is soda?
What is the soda in common use?
How do soda and potash differ, and in what respects are they similar?

The attraction of soda for acids is less than that of potash; the salts of soda are decomposed by potash, which attracts from them their acids. Soda forms with oil hard soap; potash with oil, forms soft soap. Soda is used in the manufacture of glass, and is for this purpose preferred to potash. Both the carbonate of soda and that of potash are used in weak solutions, to correct acidity of the stomach. Potash is found in the mineral kingdom; as in felspar, one of the constituents of some of the primitive rocks, it composes 10 parts in 100. Soda is the basis of common salt, and therefore extensively diffused throughout the mineral kingdom in beds, and even mountains of salt, and in the waters of the ocean, and salt lakes and springs.

Common salt is a *muriate of soda*, or according to the present state of chemical science, a *chloride of sodium*. Glauber's salts is a *sulphate of soda*.

Sodium, the *element* which forms the basis of soda, is obtained by means of galvanic decomposition, it may also be obtained by being heated in a gun-barrel with iron filings, which take up the oxygen, and the melted sodium flows down in a liquid state. Potassium may also be obtained by this latter mode, which was first practised by two distinguished French chemists, Gay-Lussac and Thenard. In many of its properties, sodium resembles potassium.

The weight of sodium compared with hydrogen is 24; combined with 1 atom of oxygen, 8, it forms the oxide of sodium or soda, represented by 32.

LIME.

Combination of Calcium and Oxygen.

Lime was known to the ancients; probably not so early as the attempt to build the tower of Babel, for it is

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What are the chemical names of common salt and Glauber's salts?
How is sodium obtained, and what metal does it resemble?
What is the weight of sodium and soda?
Was lime known to the ancients?

said in Scripture, that they had bricks for stone, and *slime* for mortar. This slime was a substance dug from pits in the earth, about India and some other parts of Asia; it contained an oily, adhesive substance, called bitumen, the same with which Noah coated the ark; and the mother of Moses the little basket in which he was exposed on the banks of the Nile.

Lime was formerly called *calcareous* earth; its Latin name is *calx*, derived from the Arabian word *kalah*, to burn; from this comes *calcine*, to burn, which is applied to any mineral substance that has been subjected to high heat.

Lime is not a simple substance, but the *oxide* of a metal called *calcium*.

Lime is never found in nature free from combination, but always united with an acid, most frequently the carbonic acid. The limestone, so common in the form of marble quarries, limestone rocks, and chalk hills (as in England,) is all a *carbonate of lime*.

Chemists who wish to prepare pure lime for experiments, put some pieces of white marble into a retort, and then heat it to a red heat; a gas is driven out, which, when collected, is found to be carbonic acid—when the gas ceases to issue from the retort, the marble, if examined, will be found greatly changed—before, acids poured upon it would cause an effervescence; now, acids have no effect upon it. Its taste is very bitter and caustic. This substance is called *quick lime*, and sometimes *alkaline earth*.

For commerce quick lime is obtained by heating limestone in large kilns. The lime, thus manufactured, is used for white-washing and making mortar.

What was lime formerly called?
Is lime a simple substance?
Is it found pure in nature?
How is pure lime prepared?
How is the lime used in commerce obtained?

It is probable that most who study this book, have observed the process which is called slacking lime. When white-washing is to be done, the quick lime is put into a tub or pail, and water gradually poured upon it. It absorbs a great deal of water; about 700 times its own weight. The lime will not, at first, appear moistened by the water, because it absorbs it so rapidly; a hissing noise is heard, and soon the lime begins to fall to pieces. So much heat is given off as to set fire to tinder. This is because a liquid, viz. water, becomes a solid. You will remember in treating of caloric, it was said, that 'heat is given out when liquids become solids.' On continuing to add water to the lime, it forms a thick, liquid mixture, suitable for laying on walls with a brush.

Lime united to water is called a *hydrate;* so great is its affinity for water, that if it stands for a short time exposed to the atmosphere, it attracts moisture from it and slacks itself, or becomes a *hydrate of lime.*

Lime is not, itself, easily fused or melted, but it greatly promotes the melting of other substances, and on this account is called a *flux.* Clay which contains lime cannot be used for pottery, because the vessels made of clay must be baked, and the lime would cause them to melt while they were exposed to the necessary heat.

The *carbonate* of lime is marble. The *sulphate* of lime is plaster of Paris, or gypsum. The *phosphate* of lime exists in animal bones.

The uses of lime in its various combinations, and in a pure state, are many and important in building, statuary, manufactures, agriculture, and medicine.

Calcium, the metallic base of lime, was discovered by

Describe the process in slacking lime.

Why cannot clay, which contains lime, be used in pottery?

What are some of the combinations of lime, and what are their common names?

What is said of the uses of lime?

Berzelius of Sweden, in 1808, the year after the discovery of the bases of potash and soda. The weight of calcium is stated as 20, this being united to one atom of oxygen, 8, forms lime, or the oxide of calcium, which is represented in Chemistry by 28.

We have now considered three of the most important alkaline metals, viz. *potassium*, *sodium*, and *calcium*, the others are *lithium*, *barium*, and *strontium*.

Lithium, (from *lithos*, a stone.)

Lithium is the newly discovered metallic basis of *lithia*, an alkali found in a mineral called *petalite*, also in the *tourmaline*, and some other minerals. Lithium is a metal of a white colour, resembling sodium in its properties, especially in being the base of an alkali.

Barium.

Barium is the metal of a mineral called *barytes*, (from the Greek *barus*, heavy;) it is found in many places in the United States; generally in the form of sulphate of barytes. As barytes combines with acids to form salts, viz. a nitrate, carbonate, and sulphate of barytes is very caustic to the taste, and gives the alkaline test with different colours, it is very properly classed among the alkalies. Its base, barium, is very little known. It is much heavier than the other alkaline metals which we have noticed, its atom being 70—thus the chemical equivalent for barytes or the oxide of barium, one atom

of barium being	70
one do. oxygen	8
is	78

What is said of calcium, and of the weight of its oxide?

Which are the three most important alkaline metals, and what others remain to be considered?

What is said of lithium?

Describe barium.

Strontium.

Strontium is the metallic base which forms, by its union with oxygen, an alkaline mineral called *strontia;* this received its name from Strontian, in Scotland, where it was first discovered in a lead mine. Strontia gives a blood, red colour to burning alcohol; for this purpose it is sometimes used to give a peculiar effect to fire in theatrical representations. This mineral is said, by Prof. Eaton, to exist on an island in lake Erie, in the state of a sulphate. The base of strontia or strontium, was discovered in the same manner as that of the other alkaline metals and about the same time. The metalloids which remain to be examined are called *earthy metals.*

CHAPTER XX.

Metalloids, or Earthy Metals.

We have in the last chapter considered certain substances which before the late discoveries of Davy and some other Chemists were called simple *alkalies;* but are now known to be compound, consisting of a metallic base united to oxygen; these bases are called *alkaline* metals.

There is another class of minerals which were called *earths,* and considered as elementary substances; these

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Describe strontium.
What is said of the substances considered in the last chapter?
What is said of the minerals called earths?

are now regarded as compounds, consisting of oxygen united to metals called *earthy metals.* Their oxides are white and of an earthy appearance, and do not generally exhibit strong, alkaline properties.

MAGNESIA.

Compound of Magnesium and Oxygen.

The common magnesia which is used for medicine is an *oxide of magnesium ;* it is a white, soft powder, without odour or taste. This substance is very common in nature. It usually exists as a carbonate of magnesia, and is obtained pure for medicine by heating, it until the carbonic acid is driven off; it is then called *calcined magnesia,* and is sold in the form of a loose powder—the carbonate of magnesia is sold in little square cakes.

The atom of magnesia is reckoned as 12
that of oxygen being 8
the equivalent of the oxide —
of magnesium is 20

Magnesia forms a part of the clay used for porcelain; it is one of the constituents of rocks, especially soapstone, or, as they are called in geology, *talcose rocks.* These are remarkable for their property of resisting fire, which they owe to magnesia, one of the substances most difficult to fuse of any known to the chemist. Magnesia is generally obtained from the sulphate of magnesia.

SILEX.

Compound of Silicon and Oxygen.

Silex exists in almost all stones and earth; it is the gritty part of them. Quartz is almost wholly composed of silex, as also flint, the Latin for which, is silex, originally derived from an Arabian word *Selag.*

What is said of magnesia?
Where does silex exist?

Silex has been known from the earliest times. The ancient chemists called it *vitrifiable earth*, because it was melted to make glass. Afterwards it was named silex, but is now known as the *oxide of silicon;* it being a compound of oxygen with silicon.

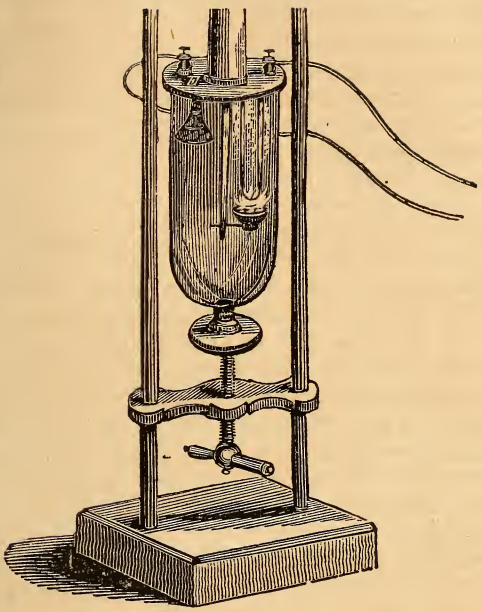
Mixed with potash or some other alkali, sand (which is mostly silex,) is melted to form glass;—the dark coloured glass such as you see in common junk bottles, is made from impure sand which is mixed with some oxide of iron; the finest and clearest glass is made with pure, white sand. The ancients understood the process of making glass. Glass beads were found upon the mummies in the catacombs of Egypt, supposed to have been placed there 1600 years before Christ. But glass as an article of common use was not known until the thirteenth century; about this time some of the nobles of Europe began to have glass windows in their houses. The articles which are sold by jewellers as an imitation of precious stones, and called *paste*, are composed of very fine glass, coloured by the oxides of metals—thus we have green in imitation of the emerald, violet of the amethyst, red of the ruby, and limpid of the diamond, the latter however, is colourless.

Silicon, though classed among the metals, is thought by some chemists to be improperly placed here. Berzelius of Sweden, who has made many experiments upon it, asserts, that it bears no resemblance to any of the metals, but is, in some respects, like carbon and other of the combustible non-metallic substances.

What was silex formerly called, and what is its name in Chemistry?

What is said of making glass?

What does Berzellius assert respecting silicon?



We have here the representation of part of an elegant apparatus, invented by Dr. Hare, for the purpose of obtaining *silicon*, from fluo-silicic acid gas, which is a compound of fluorine and silicon. A bell glass is so fixed that it may be easily exhausted of air, by an air pump; a platina wire is suspended within the bell glass and a cup containing potassium, hangs just below the wire—after the air is exhausted from the bell glass, and fluo-silicic acid gas admitted, the platina wire is ignited by an electric spark communicated to a part of the wire extending without the bell glass, this inflames the potas-

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Describe Dr. Hare's method of obtaining silicion from fluo-silicic acid.

sium, which burns and decomposes the fluo-silicic acid, giving rise to a peculiar, deep red flame, and chocolate coloured fumes, which condense into flakes, resembling (except in colour,) a miniature snow storm. On washing the substance which is collected after this combustion, pure *silicon*, which is insoluble is obtained; the residue is chiefly *fluoride of potassium.*

ALUMINE.

Compound of Aluminum and Oxygen.

The name *alumine*, is from alum, which has this earth for its base. Alumine is very abundant in nature, existing in clay, and giving it that peculiar quality necessary for the manufacture of porcelain. In all manufactures of bricks and pottery, whether of the coarsest kind, as the gardener's flower pots, or of the most beautiful porcelain vases, alumine and silex are essential constituents. The rudest nations know something of the art of making vessels of wet sand and clay, hardened by baking.

Felspar one of the minerals which is of important use in making fine, porcelain ware, consists in 100 parts, of silex 65, alumine 25, and potash 10. All these constituents are important in the manufacture of porcelain ware.

Alumine is obtained by chemists for experiments, by the decomposition of alum (*Sulphate of alumine.*) To a solution of alum, carbonate of potash is added; a carbonate of alumine is precipitated. The carbonic acid is driven off by heat, and pure alumine obtained.

Aluminum, the metal of alumine, burns readily in the air; the produce of the combustion, is the oxide of aluminium or alumine. The metal is obtained by the anal-

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What is said of alumine?
How is it obtained?
What is said of aluminum, and what is the weight of its oxide?

ysis of the earth alumine. The combining weight of aluminum being 10
oxygen 8

The chemical equivalent of oxide of alumine is = 18

Besides the earthy metals magnesium and aluminum, there are four others, *yttrium*, the base of an earth called yttria, *glucinum* the base of an earth called glucina, *zirconium* the base of the earth zirconia, and *thorium* the base of the earth thorina; but as these metals are little known and the earths in which they exist unimportant, we shall not dwell upon them. They very properly demand the attention of chemists whose duty and whose pleasure it is to search into the secrets of nature, and to discover, as far as possible, the properties of every existing thing in her vast kingdom.

There may be among the young persons who are gaining from this book the first elements of the science of Chemistry, those who are destined to make discoveries even greater than any preceding chemist has yet done.

There was a time when the terms used in Chemistry sounded as new and strange to the ears of Davy, and Berzelius, and to our great American chemists, as they now do to you. They have attained their eminence, they have benefitted science but by long and patient exertion; —and are there not among the youth of our country, those, who inspired by the example of our own scientific men as well as those of foreign countries, will bestir themselves, that they may become worthy to succeed those whose places will ere long be vacant, and that they may attain strength to gird themselves with their armour when they shall lay it aside forever?

Hopes like these encourage the author who labours to prepare simple works of instruction for the young.—

What is said of some other substances which belong to the class we have been considering?

What remarks close this chapter?

This is not a field for honour and fame; but as the parent toils cheerfully, to elevate his children beyond his own sphere, so we labour, cheered with the thought that our humble efforts may be the means of raising up among the children of our country, those who are, hereafter, to add to her glory and prosperity.

CHAPTER XXI.

Metals.

Even young children know something of the character of metals. They can tell their silver six-pence from a copper cent; and they understand that silver is more valuable than copper, and that gold is more valuable than silver; they know that the pot is made of iron, and the andirons of brass, and the the shovel and tongs of steel. There are probably few who study this book that could not readily answer if asked which is the most useful metal. They know that iron is used for almost every kind of machinery, for stoves, cooking vessels, and other domestic utensils, as the plough, the hoe, and spade.

Metals are not usually found pure in nature, but in the state of *ores*, that is, connected with minerals of various kinds, from which they are separated by different means, chiefly by a process called *roasting*—the metal being

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What is said of the general knowledge which all have of metals?

What is said of refining metals?

generally more easily melted than the earths or stones to which it is united, runs down in a liquid state, and is thus separated from them. In some cases as in the *sulphurets* of metals, the sulphur is driven off or sublimed by heat, and the metal remains. The art of refining metals is of great importance and requires much care and experience as well as science; it is called *metallurgy*.

The knowledge of metals is of great antiquity. Tubal-Cain, the grandson of Methuselah, was an artificer in brass and iron.

1. The metals possess a peculiar brilliancy called a *metallic lustre*.

2. They are *opaque*, that is, the rays of light do not pass through them.

3. They *fuse* or melt at different temperatures. Mercury is liquid at the ordinary temperature and even below zero. The metal called platinum can be melted only when exposed to a stream of oxygen gas, directed upon burning charcoal. Mercury is therefore the most fusible of the metals and platinum the least so.

4. The metals are good *conductors of heat and electricity*.

5. Metals when combined with other substances, always *go to the negative pole* of the galvanic battery.

6. They *reflect light* powerfully; this causes their metallic lustre.

7. The metals were all formerly considered as *heavier* than water; but since the discovery of potassium and sodium which are lighter than this substance, a density greater than water is not ranked among the properties of this class of elements. Platinum, one of the heaviest metals, is 23 times heavier than water.

8. Metals *burn* brilliantly and with different coloured flames, when subjected to the action of galvanism.—Lime or the oxide of calcium can be volatilized and become vapour by a very intense heat.

Were metals known to the ancients?

Mention some of the most important porperties of metals.

9. The *tenacity* of metals depends on their cohesive attraction; this is the power they possess of bearing weights. An iron wire, one tenth of an inch in diameter, will hold a weight of two pounds. Iron has more tenacity than any other metal.

10. Metals are said to be *ductile* when they can be drawn out into wire. Gold and platinum are most remarkable for this property.

11. *Malleable* refers to the property which metals have of being hammered or rolled into thin plates. Gold possesses this property in the highest degree.

12. The *colour* of metals is various, but they generally appear white, gray, red, or yellow.

The first rude attempts made in Chemistry, were in the fourth century, by a set of men called alchymists, who laboured with great patience and perseverence in experiments to change the baser metals into gold.

Metals have a *strong affinity for oxygen*, though in very different degrees. Iron attracts it from the air; therefore it rusts easily, for the rust of a metal is caused by its union with oxygen,—rust is, therefore, the oxide of a metal. Gold and silver do not attract oxygen from the air or water; therefore they do not rust easily. Gold for this reason, is used for filling cavities in the teeth—even the acid substances which are taken into the mouth with food in various ways, do not oxidate gold. Silver oxidates more easily, and therefore when used in the same way, soon becomes discoloured and tarnished.

The oxides of metals *unite with acids and form salts;* thus the sulphate of soda is a salt formed by the union of sulphuric acid with soda which is the *oxide of sodium.*

Metals *unite with each other*, and form a class of bodies called *alloys.* These furnish some of the most important materials for the use of mankind. Brass is a com-

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By whom were the first rude attempts in Chemistry made?

What is said of the affinity of metals for oxygen?

What substances are formed by the union of the oxides of metals with acids?

pound of copper and zinc; pewter of tin and lead; and bell-metal of copper and tin. Mercury combines with other metals and forms *amalgams.**

The ancients were acquainted with but *seven* metals, viz: gold, silver, copper, mercury, iron, tin, and lead. These are still the most important to mankind, notwithstanding many others have been since discovered.

CLASSIFICATION OF METALLIC SUBSTANCES.

All metals may be divided into two great classes.

CLASS I.—METALLOIDS.

Metalloids have properties in common with the true metals, but they differ from them in being much lighter, and in having so great an affinity for oxygen that they absorb it from the atmosphere in a dry state. This class we divide into two orders.

Order 1.—*Alkaline metals*, or metalloids, whose oxides are *alkalies;* these are *Potassium*, *Sodium*, *Calcium*, *Lithium*, *Barium*, *and Strontium.*

Order 2.—*Earthy* metals, or metalloids, whose oxides are *earths;* these are *Magnesium*, *Silicon*, *Aluminum*, *Ittrium*, *Glucinum*, *Zirconium*, and *Thorium.*

* With silver, mercury readily unites, to form an amalgam. Two little girls wishing to do some meritorious act in the absence of their mother, attempted to brighten her silver spoons by rubbing them over with quicksilver (mercury). At first they were delighted with their success, but they found, that on coming in contact with other substances, the spoons tarnished and looked dark coloured like old pewter—the little girls were then greatly troubled, believing they had spoiled the spoons. When their mother returned, they very sorrowfully informed her of the accident; she told them that the mercury had formed an amalgam with the silver, but that by heating the spoons it would be driven off and the silver restored; she advised them however, not to attempt making experiments upon articles of so valuable nature, until they had more experience.

What are alloys and amalgams?
What metals were known to the ancients?
Describe the first class of metals and the orders it contains.

CLASS II.—THE PROPER METALS.

This class we divide into two orders.

Order 1.—*Metals which are of important use to man, either in agriculture, for domestic purposes, or in the arts;* these are *Platinum*, *Gold*, *Silver*, *Mercury*, *Copper*, *Iron*, *Lead*, *Tin*, *Zinc*, *Bismuth*, *Antimony*, *Cobalt*, *Arsenic*, *Manganese*, and *Chromium*.

Order 2.—*Metals which are of little use in the arts;* these are *Palladium*, *Rhodium*, *Iridium*, *Osmium*, *Nickel*, *Cadmium*, *Tungsten*, *Uranium*, *Tellurium*, *Titanium*, *Molybdenum*, *Columbium*, *Cerium*, and *Vanadium*.

Of the first class, or the Metalloides, we have already treated; these we found to be of little importance, except as exhibiting the compound nature of substances until lately considered simple—we therefore paid more attention to the oxides of these metals, than to the metals themselves. Potash, soda, and lime are known to almost every one, while potassium, sodium, and calcium, their metallic bases, are scarcely known beyond the chemist's laboratory. Potassium is indeed of great use to the chemist, in enabling him to decompose other substances, a fact which has been already mentioned. The metals of the second class we shall now briefly notice.

Platinum, was so called by the Spaniards, from the word *plata*, which, in their language, signifies silver. The largest mass which has been found of this metal, does not exceed a pigeon's egg in size. It is found in the vicinity of the Rio de la Plata, in South America, and with it are found the four new metals *palladium*, *iridium*, *osmium*, and *rhodium*. Pure platina is the heaviest of all known substances. Its specific gravity in comparison with water is 23. On account of its hardness, infusibility, and difficulty of being acted on by most substances, it is of great value for making vessels to be used in chemical experiments.

How are the proper metals divided?
What is said of the metals of the first class?
What is said of Platinum?

Gold was called by the ancients the 'king of metals.' Its *specific gravity* is 19; it is the heaviest of all known substances except platina. No substance is capable of such *extension* as gold. One ounce of gold can cover a wire that may be extended more than 1300 miles. The thin sheets of gold called gold leaf are the lightest of all solid substances. Gold melts at 1300° of F., which is above red heat. It does not *oxidize* by exposure to the air, heat, or moisture, and may therefore be preserved for ages without change. When exposed to the action of the galvanic battery, gold leaf burns brilliantly with a red light, and an oxide of gold is the product of the combustion. There is but one acid which can *dissolve* gold; this is the *nitro-muriatic*, or a mixture of nitric and muriatic acids. Chlorine gas, warmed, sets fire to gold. The gold coin of the United States is alloyed with about one part in twelve of a mixture of copper and silver. The chemical equivalent of gold is 200.

Silver. The alchymist called silver *Luna*, or the moon, and they also called gold *Sol*, or the sun. Silver and gold were called by the ancients *precious metals*, and also *noble metals.* It is unnecessary to tell those who study this book what the colour of silver is, and whether it exists in the state of a liquid or a solid. Our silver dollars, half dollars, and the smaller pieces of silver coin are known to all—silver spoons, which were formerly only used by the rich, are now very common. They seem indeed to be almost an article of necessity, since silver is little acted upon by acids or other substances which corrode iron and blacken pewter. From the fact that silver is little affected by acids, you will perceive that it has not much affinity for oxygen. It resembles gold in many of its properties. Nitric acid dissolves silver, forming *nitrate* of silver, commonly called *lunar caustic; lunar* from the ancient name of

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What is said of Gold? What is said of Silver?

silver, and *caustic*, from its power to act upon and decompose animal substances. The silver is separated from its combination with nitric acid by many other metals—if a piece of bright copper is immersed in a solution of nitrate of silver, it will be instantly covered with beautiful white crystals of silver. The chemical equivalent of silver is 110.

Mercury is commonly called *quicksilver;* the alchymists gave it this name because they supposed it to be silver in a fluid state, quickened by some substance which they hoped to expel, that they might obtain from it solid silver. The name, mercury, is from that planet, which the alchymists supposed had a peculiar influence upon the metal. This is the only metal which is fluid at the common temperature. You can see it in thermometers and barometers, and on the backs of looking glasses, where it is laid over tin-foil, making with it an amalgam. At 40° degrees below zero, a cold which is produced by mixing nitric acid and snow, mercury becomes solid, and may be cut with a knife, and flattened by a hammer. At 656° of heat mercury can be made to boil, and is converted into a vapour. With oxygen mercury forms compounds which are of great importance in medicine. An article in great use by physicians, called the *blue pill*, is an oxide of mercury; another medicinal article called *red precipitate*, is an oxide with a higher portion of oxygen. Chlorine forms with mercury some important combinations which will be mentioned under the head of *chlorides.* Mercury is found in a pure or native state, and as an ore in various parts of Europe and South America. This is one of the most useful metals; its importance in science is very great, as without the thermometer and barometer, no precise principles could be established with respect to heat and its effect on substan-

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Give some account of Mercury.

ces, or any certain observations be made of the pressure of the atmosphere. Medicine owes to mercury some of its most powerful and effective agents.

Copper was first known in the island of Cyprus, from whence came the Latin name *cuprum*, and the English copper. The brass of the ancients is by some supposed to have been an alloy of copper and tin, but they seemed to have used the words, copper and brass, as synonymous. The colour and other external properties of copper it is unnecessary to enumerate, since in the form of coin, as cents, and in various articles in common use it is known to all. Copper is not affected by the dry atmosphere, but when in contact with damp air, its surface becomes covered with the oxide of copper. It is *combustible*, and burns under the compound blow-pipe with great brilliancy, throwing off a green coloured flame. Copper alloyed with zinc forms *brass*, with a different proportion of zinc it forms *pinch-beck*. Copper forms various alloys with tin, as *bell-metal*, *cannon-metal*, bronze and a coating for the inside of copper vessels. Copper is found in a pure state, in the state of an *oxide*, *a sulphuret*, *a sulphate and a carbonate*. It should be known by all housekeepers that the compounds of copper are highly poisonous. Clean and bright copper vessels may be used with safety for scalding pickles in vinegar, for making sweetmeats, and in other culinary operations ; but substances should not be allowed to stand in them. For instance, vinegar contains acetic acid; if this stands, for any length of time, in a copper vessel it corrodes it, forming an *acetate* of copper a very poisonous substance known under the name of *verdigris*.

Iron. The affinity of this metal for oxygen is very great. You will recollect that iron filings decompose water by uniting with its oxygen, and that hydrogen gas is collected in this manner. So great is the affinity of

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What is said of Copper? Of Iron?

iron for oxygen, that even at the common temperature it decomposes water; thus if you leave a little water to stand a few days in an iron vessel, it will appear rusted; iron rust is an *oxide of iron*. Even if left to stand dry for any length of time, iron will oxidate or rust by attracting oxygen from the air. Iron is the most useful of metals, and the Creator and Benefactor of man, has caused it to exist in great profusion in every country. Our own country is very rich in iron ores. New villages within a few years past, in consequence of the discovery of iron ore, have sprung up in the wilderness, and the busy hum in industry is now heard where silence and desolation lately reigned. Most mineral substances contain some iron. It is found in the state of an *oxide*, *a sulphate*, *sulphuret*, *carbonate*, &c.; but the oxides are the ores from which the metal is obtained. Iron combined with carbon forms *steel*, which is a carburet of iron; existing with a greater proportion of carbon, it forms *black lead or plumbago*.

Iron, as you have already seen, burns brilliantly in oxygen gas. Even in the common air, as may be seen in the blacksmith's shop, a bar of iron heated to a white heat throws out brilliant sparks when withdrawn from the fire. Iron is a good conductor of heat and electricity; it is the basis of ink-powder.

Lead, was by the ancients called saturn, who in Mythology, is said to have devoured his children: thus lead *absorbs* all the metals, except gold and silver. Lead is a soft metal of a bluish white color; it is not very *ductile*, but very *maleable*, as it can be beaten into thin leaves. It melts easily. When black lead pencils, and sheets of ruled lines were less common than at present, plummets of lead were made by children for ruling their paper. These were made by melting lead and pouring it into moulds. Nitric acid easily dissolves lead but sulphuric and muriatic acids have little effect upon it. It combines with oxygen in three proportions forming a *protoxide*,

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What is said of Lead?

deutoxide and *peroxide.** Lead is sometimes found pure, but more generally in combination with sulphur, forming a sulphuret, called in mineralogy *galena.* This is very common and when once known is easily recognized by its fine metallic lustre.

A beautiful experiment may be made by suspending from the stopper of a decanter a small piece of zinc in a solution of the *acetate* of lead; if suffered to stand undisturbed a few days, a beautiful figure will be formed resembling a tree, this is called the *lead tree.* The zinc attracts the acetic acid from the solution of acetate of lead and the lead being precipitated from this combination collects upon the zinc, branching forth in various directions. The salts of lead are mostly very poisonous.

Tin. On account of its splendid appearance like that of the beautiful planet Jupiter, it was by the alchymists called by that name; they thought there was some intimate connection between the planets and the metals, and that the number of each being equal, (as they then reckoned but twelve of each,) they thought each planet had its metal, and each metal its planet. These strange notions of the people in remote ages seem to us quite ridiculous, but we must recollect that with all our boasted knowledge, those who come after us may be as much surprised at many of the opinions we now hold, as we are at those of our predecessors.

Tin is very flexible; it dilates much by heat and is among its best conductors. It attracts oxygen from the air, less freely than some of the metals, of course it does not rust so easily. It melts more easily than any metal except potassium, sodium, and mercury; lead stands next below tin in *fusibility.* Tin burns brilliantly in the focus of the compound blow-pipe with a lively white

* For an explanation of these terms see oxides.

Describe Tin.

flame; the result of the combustion is a white *oxide of tin.* Tin combines with but two simple combustibles, sulphur and phosphorus. An alloy of tin with zinc, and sometimes with other substances, forms pewter. Tin is not found in this country; the most important tin mines known are in Cornwall, England.

Zinc; this metal has a bluish white colour, and a strong metallic lustre; it is obtained from two ores, the carbonate of zinc, called *calamine*, and the sulphuret of zinc, called *zinc-blende.* The zinc of commerce was formerly brought entirely from China, as the secret of obtaining it from its ores was not known to Europeans. It is now manufactured in Europe in great quantities; and exists in many places in the United States. Zinc has a strong affinity for oxygen, and is therefore often used for obtaining hydrogen, by the decomposition of water; it is for the same reason used for the positive side of the galvanic battery;—you know that oxygen always goes to that side. Zinc is very *combustible;* if a small quantity is put into a crucible, it may soon be heated by a common furnace and made to boil; a little more heat causes it to burn; a light white substance rises and floats about the room—this was formerly called *white nothing*, and *philosopher's wool.* It is the *oxide* of zinc.

Bismuth is a metal of a reddish white colour; it is very brittle and fusible. A preparation of bismuth forms the *pearl powder*, which has already been named as being in use as a cosmetic, and which becomes dark coloured by the vapour of sulphur, hydrogen and phosphorus. A solution of the nitrate of bismuth forms a *sympathetic ink;* letters written with it although at first invisible, when exposed to sulphuretted hydrogen gas become distinct and legible. Bismuth is not found abundantly; one locality only is known in the United States, this is in Connecti-

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What is said of Zinc? Of Bismuth?

cut, where it is found in connection with silver, galena, zinc blende and some other minerals.

Antimony. The name of this metal is said to be derived from *anti*, against, and *monakos*, a monk, it having been first applied to medicine by Basil Valentine a Benedictine monk, who, using it injudiciously among the brethren of his order, killed many of them. It is of a greenish white colour, and very brittle; it is seldom found pure in nature. The sulphuret is the most abundant of its ores. It is a constituent of the metal of which printer's types are made. With tartaric acid, (an acid obtained from the fermentation of grapes,) and potash, antimony forms an important medicinal substance called *tartar emetic.*

Cobalt, is found in connection with ores of iron, copper, and arsenic, and is separated from them by subjecting the ores to a high heat. These ores were used in Europe, as early as the fifteenth century, for the purpose of colouring glass blue; but it was not, until the last century that they were known to contain a peculiar metal. Solutions of cobalt form *sympathetic ink*, that is, an ink which is invisible, until a certain process is gone through. The nitrate of cobalt, when pure, is of a beautiful blue color, or if iron is present, of a pea green; when much diluted it is a pale rose or pink. Writing with this solution appears invisible on white paper when cold, but when held to the fire, it takes a blue or green tinge, and the writing is legible. 'Paper fire screens are sometimes adorned by drawings of trees, whose trunks and leafless branches, are sketched in india ink, or other appropriate colours (representing a winter scene) and the foliage is made with the invisible solution of cobalt; on bringing it near the fire, the green leaves at once appear, (and spring returns.' *) It is supposed that

* Silliman's Elements of Chem.

What is said of Antimony? Of Cobalt?

this effect is caused by the agency of oxygen, in some manner not well understood. Most of the cobalt of commerce is obtained from a combination with arsenic, called *arsenical cobalt.* In Saxony, this manufacture is very extensive, and carried on by criminals who are condemned to this labour for crimes, that by law, deserve death. The fumes of the arsenic which is a deadly poison, render the business destructive to health and life, and wretched must be the existence dragged out by the miserable beings who are thus cruelly punished. The children of luxury when partaking of their rich beverage from porcelain cups painted with the beautiful blue of cobalt, think not of the dreadful sufferings their fellow creatures have endured in order to procure this costly embellishment. An oxide of cobalt mixed with silex forms a substance called *zaffre;* this heated with sand and potash forms a beautiful blue glass called *smalt;* and this latter powdered very fine is called powder-blue. This is said to be more delicate than indigo for bluing muslins and laces. 'The name, cobalt, is said to be derived from *cobalus,* the supposed demon of mines, who opposed the operations of the miners, and this metal appearing at first mysterious and untractable, was nicknamed cobalt.' It is found in Chatham in Connecticut, and Franconia in New Hamshire.

Arsenic; this metal is supposed to have derived its name from an arabic word, *arsanek,* signifying strong and deadly qualities. Arsenic is obtained by roasting the ores of cobalt; as it is volatile, it vapourises and condenses in receivers prepared for that purpose. Arsenic may be detected, by its strong smell of onions or garlic, when thrown upon burning coals; in burning, it unites with oxygen and forms the oxide of arsenic, or as some consider it *arsenious* acid. With the alkalies, this forms salts called *arsenites.* The deutoxide of arsenic is this metal with a greater portion of oxygen, by some considered as *arsenic*

What is said of Arsenic?

acid; combined with alkalies, as potash and soda, it forms salts called *arseniates.* The equivalent number of the metal arsenic is 38. King's yellow—which is considerably used in painting, both in water colours and oil, is made of a *sulphuret* of arsenic, called *orpiment.* People who make use of these colours, ought to be very careful never to put paint brushes into the mouth as most of the colours are based upon poisonous substances.

Manganese. The affinity of this metal for oxygen is such that it is never found in a mere metallic state, but, always as an oxide. It is found in connection with iron ore which it resembles in colour, and other external properties. You will recollect that the peroxide of this metal, (that is, the oxide with the most oxygen,) gives off oxygen when heated to a red heat. The equivalent of manganese is 28. It is not of much use, except in Chemistry to furnish oxygen and chlorine gases. The latter gas is obtained by the agency of manganese on principles, respecting which, chemists have not agreed. The peroxide of manganese, and muriatic acid (hydrochloric) are put into a vessel and exposed to heat; chlorine gas is then given off. It is supposed that the muriatic acid decomposes; that its hydrogen unites with the peroxide of manganese, and one part of the liberated chlorine combines with the manganese, while the other portion is disengaged; there is then in the process a formation of water, of the chloride of manganese, and a disengagement of chlorine.* On account of the utility of manganese in disengaging chlorine from muriatic acid and common salt, it is indispensable in the bleaching processes of manufactories.

Chromium; the name of this metal is from the Greek *kroma,* colour, because it is remarkable for giving colour to its combinations. The metal is of no use in its pure

* See Dictionary of Chemistry, page 159.

What is said of Manganese? Of Chromium?

state; it is generally found combined with oxygen. There are two *oxides* of chromium, the protoxide which is green, and the deutoxide which is brown; the chromic acid, which is the same metal with a higher portion of oxygen, is scarlet. The compounds of this acid with bases are called *chromates;* these salts are all coloured.

The metal, chromium, was first obtained by the celebrated French chemist, Vauquelin, from the chromate of lead, a brilliant yellow substance, used as a paint under the name of *chrome yellow.* Chromium is the colouring matter of many minerals; the emerald is coloured green by its oxide, the ruby red by its acid. Chromate of iron is found in marble and serpentine, and in connection with the oxide of iron is thought to produce the green and most other colours with which they are variegated.

We have now given a sketch of the principal characteristics of the most important metals We shall do little more than name the metals of the 2d order of the class of proper metals.

The following metals have been found in connexion with the ore of platinum.

1. *Palladium,* was discovered in 1803 by Dr. Wollaston. It is a very rare metal. It was named after the late discovered planet, Pallas.

2. *Rhodium,* was discovered by Dr. Wollaston about the same time that he found palladium, and in the same metal. It has been combined with several of the metals but it is too rare to be applied to any use. Its name is from the Greek *rodon,* a rose, on account of the rose colour of its salts.

3. *Iridium,* a metal found in connexion with another called osmium, in the ore of platinum. The name (from Iris the rainbow,) is given in allusion to the changeable colour of some of its solutions. Accor-

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What orders are we now to consider?

What four metals have been found in connexion with platinum ore?

ding to Berzelius, as quoted by Silliman, 'solutions may, without the aid of foreign matter, be obtained with all the colours of the rainbow.'

4. *Osmium*, from the Greek *osme*, odour, is named in allusion to the peculiar smell of its oxide, which somewhat resembles chlorine. It is found only in platinum ore, either combined with other metals, or with iridium.

The four metals we have just described, viz. palladium, rhodium, iridium and osmium are called *platiniferous* minerals, because they are found with platina. The method of obtaining them from their combinations is very complicated, and shows the great accuracy and delicacy of chemical analysis.

Nickel is found in connexion with the ore of cobalt; it also exists with iron in what are called *meteoric stones*,* (substances which occasionally fall to the earth from the surrounding atmosphere, and whose origin is unknown). Nickel is a white metal, somewhat like silver in appearance. It is thought to possess magnetical attraction, a property which is possessed by no other metals except iron and cobalt. It forms a green *oxide of nickel*, when heated in the air, or with oxygen. Pure nickel is never found in nature; it is obtained from its ores by a complicated process. Although a highly valuable metal, it is too rare and costly to be applied to use in the arts.

Cadmium was first discovered in 1817, in an oxide of zinc. It is a white, brilliant metal resembling tin; it receives a high polish. Though an interesting metal it is not yet obtained in sufficient quantities to cause it to rank among the useful ones. It has not been found in this country, though it is thought that it may exist with zinc in the Missouri lead-mines.

* Silliman observes that 'large masses of meteoric iron, in Siberia, Peru, Louisiana, &c. have lain in the open air apparently from age to age without rusting, or only superficially.' It is supposed that the nickel they contain prevents their rusting.

Describe Nickel. What is said of Cadmium?

Tungsten. The name of this metal signifies, in the Swedish language, *heavy stone.* It was first discovered in a mineral from Sweden, called in mineralogy, *wolfram*, but known in Chemistry as the *tungstate of iron and manganese.* There is a combination of oxygen and tungsten to form *tungstic acid;* this acid it is, which, with bases, forms *tungstates;* of these there are some with alkaline, and some with metallic bases. The metal tungsten is said by Silliman to exist in Connecticut.

Uranium, was by its discoverer named in 1789 from the Greek *ouranos*, the heavens. It was found in a mineral called *pechblend*, which is the oxide of uranium. It is obtained by calcining the ore or driving off the oxygen with heat. Combined with carbonic acid it forms *chalcolite*, or green mica.

Tellurium was named in 1789, by Klaproth, the discoverer of uranium from *tellus*, the earth; thus following the example of the ancients, who named minerals from the planets. Tellurium is a brilliant metal; it burns with splendor in oxygen gas. Silliman thinks it exists in Connecticut in connexion with the ore of tungsten.

Titanium resembles bright copper in its colour and lustre; its crystals were at first mistaken for iron pyrites in England and Scotland. It is found in primitive rocks, and exists in many places in the United States.

Molybdenum, is so called from a Greek word signifying lead; this was long supposed to be the same substance as black lead or plumbago. It does not exist pure in nature, but is found either as a *sulphuret of molybdenum* or a *molybdate* of lead; the latter substance is composed of *molybdic acid* and lead.

Columbium was first sent by Governor Winthrop of the Massachusetts colony, to Sir Hans Sloane, the founder of the British Museum. The name was given in

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What is said of Tungsten? Of Uranium? Of Tellurium? Of Titanium? Of Molybdenum? Of Columbium?

honour of the discoverer of America. The metal is of a dark gray colour. It was formerly called *tantalium.*

Cerium was discovered in 1804, and afterwards investigated by Vauquelin. It is found in a mineral called *cerite* which is the *oxide of cerium.* In some respects the metal is said to resemble iron, though it is harder and whiter.

Vanadium. This is the most recently discovered metal. It was found in 1830, in connexion with iron ore, by a director of the school of Mines of Fahlun, in Sweden. This metal is said to resemble chromium, and therefore easily mistaken for it. Since its discovery, it has been found in lead ore of Mexico, in which, twenty years before, a professor of Chemistry asserted that he had found a new metal; but he was contradicted in this by another chemist, to whom he submitted some specimens, who said it was merely impure chromium. Combined with oxygen it forms *vanadic acid,* and this with bases forms salts called *vanadiates.*

The pupil will observe that in the arrangement we have made with respect to the two orders of proper metals, there is nothing which need to confuse his mind with respect to any other arrangement which he may afterwards meet with in books of Chemistry. The division of metals into such as are useful in the arts, and such as are not, seemed the most simple and easy to be understood of any that could be made; and you will perceive that there is at present, a broad and plain distinction between them in this respect;—though it is very probable that in the progress of science, means will be found for obtaining in plenty, some of those rare metals which are now scarcely known but in name, and that they may be destined to become as common for useful and ornamental purposes as any which are now in use.

What is said of Cerium? Of Vanadium?

What is remarked respecting the arrangement of metals made in this book?

CHAPTER XXII.

Oxides. Chlorides. Salts.

Our enumeration of elements or simples substances is now completed; they consist of *imponderable bodies*, as *Caloric; Supporters of Combustion*, as *Oxygen; Combustibles, not metallic*, as *Hydrogen; Metalloids*, as *Platinum; Proper Metals*, as *Iron.*

From these substances are formed every thing, on and around the earth that we have any knowledge of—the rocky foundations of the earth, the air, the water, the vegetable creation, and the animal frame—every product of land or sea, of heaven and earth, so far as science has discovered, may be resolved into two or more of these elements.

BINARY COMPOUNDS,

Consisting of two elements.

When any *two* elements are united they form what is called a *binary compound*, (from the Greek *bis*, two.) They are of three kinds: 1. *acids;* 2. *oxides;* and 3. those which are *neither acids nor oxides.*

Acids.

Acids were long supposed to be produced by oxygen only, as its name signifies the producer of acids; but

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What classes do the elements or simple substances in nature consist of?

What are all the substances on, and around the earth composed of?

What is a binary compound, and how many kinds of binary compounds are there?

What is said of acids?

chlorine and the other supporters of combustion, together with hydrogen, have been found to form acids.

Nitric acid is composed of nitric acid and oxygen,
Sulphuric acid " sulphur and oxygen,
Carbonic acid " carbon and oxygen.

Muriatic acid, which is composed of hydrogen and chlorine, is among the most powerful of the acids, though it contains no oxygen. Prussic acid * (hydro-cyanic) is a compound of cyanogen and hydrogen, and is also a very powerful acid.

Oxides.

Oxides are formed by the union of oxygen with elements; the metallic oxides were formerly called *metallic ashes* and *burnt metals.* You have seen that the non-metallic substances, nitrogen, phosphorus, &c., form acids by their union with oxygen; but that a lower proportion of oxygen produces with them compounds which do not affect vegetable colours, nor give other acids tests; these are, therefore, called oxides, as nitric oxide, &c.; water is the deutoxide of hydrogen.

The *metallic oxides* are formed by the union of oxygen with a metal; thus when iron or copper wire is burned in oxygen we have an *oxide of iron*, or an *oxide of copper.*

Some metals unite with oxygen in more than one, and some, in more than two proportions; thus we have *protoxide* for the first degree of oxidation, *deutoxide* for the second, and *tritoxide* for the third; *peroxide* signifies the highest state of oxidation of which the substance is capable.

The most important metallic oxides are those which we have already noticed under the head of *alkaline*

* Prussic acid is not however a *binary* compound, since its base cyanogen is composed of two elements. This is a *ternary* compound or one that consists of three elements.

What is said of oxides?

metals, as the oxide of potassium, the oxide of sodium, &c.; which are the chemical names for potash, soda, &c.

Chlorides.

Another important class of *binary* compounds are the *chlorides;* these consist of substances formed by the union of *chlorine* with different metals. They were formerly ranked among *salts;*—but salts are formed by the union of oxides, being composed of *four* elements; while chlorides consist of but *two* elements. When common salt was named *muriate of soda*, it was supposed that muriatic acid was composed of a base, *muriatium*, united to oxygen, and that this acid combined with soda formed the salt: but since muriatic acid is found to consist of hydrogen and chlorine, and soda is found to have a metallic base, *dry* salt is called *chloride of sodium.* A solution of salt, the hydrogen of the water goes to the chlorine, forming hydro-chloric or muriatic acid, and the oxygen of the water goes to the sodium, forming the *oxide of sodium* or soda, and thus presents a proper muriate of soda. Dry, common salt does not then belong to the salts known in Chemistry, but to the chlorides.

Chloride of sodium, or common table salt, consists of one proportion of sodium whose

combining number is		24
one of chlorine	"	36
		60

is the number representing salt. Of the important uses of this substance in preserving meat and preparing food it is unnecessary to remark. It is of great use in bleaching manufactories, by furnishing chlorine. It is highly esteemed as a preventive of contagious diseases, and was used very extensively and with great success, under the

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What are chlorides, and why are they not properly *salts?* Describe the chloride of sodium.

name of chloride of soda, during the late alarming prevalence of the cholera in the United States.

Chloride of *calcium* is composed of chlorine and the metallic base of lime. Slacked lime which is called a *hydrate* of lime, unites with chlorine gas and forms a hydrated *chloride of lime;* this is called bleaching powder, and is useful for many of the purposes to which the chloride of soda is applied; it is less expensive.

Proto-chloride of mercury forms a very important medicine called *calomel.* The *deuto-chloride* of mercury is commonly called *corrosive sublimate;* it is a deadly poison, and is used for destroying insects and bugs.

There are chlorides of silver, of gold, and of other metals, which furnish interesting subjects for the observation of the chemist, but our limits will not permit us to examine them.

Fluorine, *iodine*, and *bromine*, the three supporters of combustion in the class with oxygen and chlorine, form, with metallic bases, *fluorides*, *iodies*, and *bromides.*

Among the binary compounds are *carburets*, *sulphurets*, *phosphorets*, *&c.;* the termination *uret*, you will recollect, is applied to combinations of the non-metallic substances among themselves.

QUARTERNARY COMPOUNDS,

Consisting of four elements.

The powerful properties of acids have been explained: *alkalies* (or the oxides of *alkaline* metals), possess properties directly opposed to these—acids are compounds consisting of oxygen or some other acidifiable element

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Describe the chloride of calcium.

What are the chlorides of mercury commonly called?

Are there any other chlorides besides those already described?

What compounds are formed by fluorine, iodine, and bromine, with metallic bases?

What other binary compounds are there, besides those which have just been named?

How do alkalies and acids differ?

united to a base; thus nitric acid is composed of oxygen and nitrogen. Alkalies are composed of metals united to oxygen, as potash which consists of oxygen and the metal potassium. Acids turn vegetable blue colours, red; alkalies turn them green. Acids (with very few exceptions) taste sour, alkalies have a pungent taste of a very different kind. Acids are attracted to the positive pole of the galvanic circle, alkalies to the negative.

The union of acids and alkalies forms *salts*, which in most cases bear no resemblance to the substances of which they are composed. These are called *neutral* salts. But there are some cases when the salt appears to partake of the character of the acid, and others in which the alkali seems to predominate.

Action of water upon the salts. Some of the salts can be dissolved in water, as the sulphate of soda (Glauber's salts); others are insoluble, as marble (carbonate of lime). This property depends on their degree of affinity for water, and their cohesion. They are more soluble in warm than cold water.

Action of ice. When pounded ice is mixed with a soluble salt, the one melts rapidly, and the other is quickly dissolved; cold is produced in consequence of the absorption of heat from surrounding bodies in causing solids to pass to a liquid state. Thus in making iced cream, common salt and ice are placed over the vessel containing the cream to be congealed.

Action of air. Some salts absorb moisture from the air and become damp; this is called *deliquescence.* House-keepers know that pearlash, (carbonate of potash,) if left exposed to the air, soon becomes wet and at length wholly dissolved. Some salts fall to powder on exposure to the air; this is called *effloresence.*

How are salts formed?
What is said of the action of water upon salts?
Of the action of ice upon salts?
Of the action of air upon salts?

Action of fire. When submitted to the action of fire some salts lose their water of crystallization, and break in pieces with a crackling noise; this is called *decrepitation;* you can observe an instance of this, by throwing a piece of common salt upon burning coals.

Action of galvanism. When submitted to galvanic action, the acid of the salt goes to the positive and the oxide to the negative pole; when the action is powerful the acid is decomposed and its oxygen then goes to the positive and its metal to the negative pole.

Actions of metals upon solutions of the salts. Metals have a powerful action upon the solutions of some of the salts. When a piece of zinc is introduced into a solution of the acetate of lead, the acetic acid having a greater affinity for the zinc, leaves the lead, which, being precipitated or thrown out of the solution, attaches itself to the zinc forming what is called the *lead* tree, already named under the article lead. There is something very curious in this process; as soon as the zinc unites with the lead, a new principle begins to operate; viz. that of galvanism. The two metals form the poles of the galvanic pile, of which the zinc is positive; the precipitating metal being always positive, and the precipitated negative. From hence arises the decomposition of the water, of the salt which was dissolved in it, and of the oxide of the metal. This property of metals to act on solutions of salt was found very destructive to ships with copper bottoms; as the plates of copper, in consequence of decomposing the salts held in solution by the water, became corroded by the action of the acids thus set at liberty. Sir Humphrey Davy again brought his scientific knowledge into the service of mankind;—by stud-

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What is said of the action of fire upon salts?
What is said of galvanic action upon salts?
Of the action of metals upon salts?

ying into the subject, he ascertained that a double lining of zinc and copper would change the electrical state of the copper, and prevent its being injured by the decomposition of sea water.

Action of the oxides upon the salts. Some oxides when brought in contact with the salts, in a state of solution, take the place of those which formed the bases of the salts. Sometimes the new oxide displaces a part of the base and combines with the salt, thus forming a double salt, as alum, which is a *sulphate of alumine and potash.*

Nomenclature of the Salts.

Names given to the salts. The acids which contain most oxygen, terminate in *ic*, those with a lower portion of oxygen terminate in *ous;* thus, we have sulphu*ric* and sulphu*rous* acids. The acid whose name ends in *ic*, forms a salt whose name terminates in *ate;* while the acid whose name ends in *ous*, forms a salt whose name terminates in *ite.* Thus, sulphuric acid forms with bases salts called *sulphates*, and sulphurous acid forms *sulphites.*

The chemical name of the salts, shows of what they are composed, and are therefore preferable to names which were merely fanciful or arbitrary; thus Plaster of Paris (or gypsum,) is now *sulphate of lime*, Epsom salts is now *sulphate of magnesia*, Salt petre is *nitrate of potash, &c.*

The salts are divided into *genera* and *species;* a genus contains such *species* as are formed by *one* acid with different bases. We will consider some of the most important genera with some of their species.

What is said of the action of oxides upon salts?
By what rule are the salts named?
Why are chemical names the best to distinguish salts?
How are the salts divided?

Genera of Salts.

Borates. Combinations of boracic acid with different bases. This genus is divided into sections;—*Neutral* borates are such salts as exhibit neither acid or alkaline properties. *Sub*-borates* are deficient in acid, or show an excess of the base exhibiting *alkaline* properties,—they are by some, called *basic* salts. The *sub-borate of soda* is the most important of them. This is called *borax*, and by its decomposition affords boracic acid. Borax is useful in promoting the melting of other oxides, and forms with them glass of various colours.

Carbonates. Combinations of carbonic acid with different substances. Most of the salts of this genus are decomposed by heat, which expels the acid. Most of the acids decompose the carbonates, by uniting with their bases and thus disengaging carbonic acid—any mineral that contains carbonic acid, will effervesce with acids. The effervescence is caused by the escape of the carbonic, as the lime unites with the new acid.

The most important *species* found in the genus carbonates, are,

1. *Carbonate of Lime;* this is one of the most abundant of all mineral substances. It is known under various names, as limestone, chalk, marble, &c. It exists in some waters in a state of solution. Pure or quick lime is obtained by calcining or heating the carbonate, and thus expelling the acid.

This salt is composed of

one proportion of carbonic acid	=22
one " " lime	28
The representative number of the salt	50

* *Sub* is from the Latin, and signifies under; *sub* salts are those which do not contain sufficient acid in their composition to neutralize the alkaline qualities of the base.

Describe the genus borates.
Describe the general character of the genus carbonates.
Describe the species carbonate of lime.

Chemistry shows us that nearly half of the matter of the solid rocks of limestone is a gas.

2. *Carbonate of Potash* is made from the ashes of vegetables; the strong ley obtained from the ashes, is evaporated till a dry substance of a dark red colour is left. This is potash, or the oxide of potassium; it is very caustic at first, but loses this property on being exposed to the air from which it attracts carbonic acid, and becomes a carbonate of potash. *Pearlash* is a more pure carbonate of potash; it is now generally sold at the shops under the name of *Sal-eratus.* The *bi* *-carbonate of potash, is formed by passing carbonic acid into a solution of the carbonate which thus receives a second portion of the acid. This is reccommended as a valuable medicine for removing acidity in the stomach.

3. *Carbonate of soda,* is prepared like the salt we have just described, except that the ashes of sea-weed, or vegetables growing near salt-water are used. It is commonly known by the name of *Soda.*

4. *Carbonate of magnesia,* is sold by apothecaries in cakes or lumps.—It is used in medicine, but is less valuable than *calcined magnesia,* or that from which the carbonic acid has been expelled.

5. *Carbonate of copper,* is found native in a mineral called *malachite* of a beautiful green colour; it also collects like a green rust upon copper vessels exposed to the air. The blue paint *verditer,* is an impure carbonate of copper.

6. *Carbonate of Lead,* is the *white lead* used by painters; it is prepared by exposing sheet lead to the vapour of vinegar; the fumes of the acid, first form the oxide of

* From the Greek *bis,* two.

Describe the species carbonate of potash.
What is said of the carbonate of soda?
What is said of the carbonate of magnesia?
Of the carbonate of lead?

lead, and this gradually attracts carbonic acid, from the atmosphere and becomes a carbonate. *

7. *Carbonate of barytes*, was discovered by Dr. Withering in the lead mines in the north of England, and is known in mineralogy by the name of *witherite.*

8. *Carbonate of Ammonia*, is a white powder used in smelling bottles under the name of *salts of hartshorn.* It is the product of animal substances, by the action of heat.

II. Genus chlorates. The salts of this genus are composed of chloric acid and bases; they are never found in nature, but are the product of art. They were formerly *called oxymuriates.* The difference between them and chlorides may be thus stated;—a chloride is a *binary* compound, consisting of chlorine and a simple element; chlorates are *quaternary* compounds, consisting of chloric acid, (chlorine and oxygen) united to an oxide, which consists of two elements. It might be said here are but three elements, oxygen and chlorine, and the base of the oxide, as the oxygen of the oxide cannot be called a fourth element, when it has been already counted—but you must observe that in the salts, the four elements are not all mingled together, but two binary compounds, viz.; the acid and oxide must unite to form them; and thus we consider the oxygen of the acid and that of the oxide as *distinct*, though not different elements. From what has been observed you will perceive that chlorides differ much in their composition from chlorates; the former are sometimes improperly classed among salts, but do not belong to them more than acids, oxides or any other binary compound.

* Although carbonic acid is not a constituent portion of the atmosphere, yet some portion always exists in it.

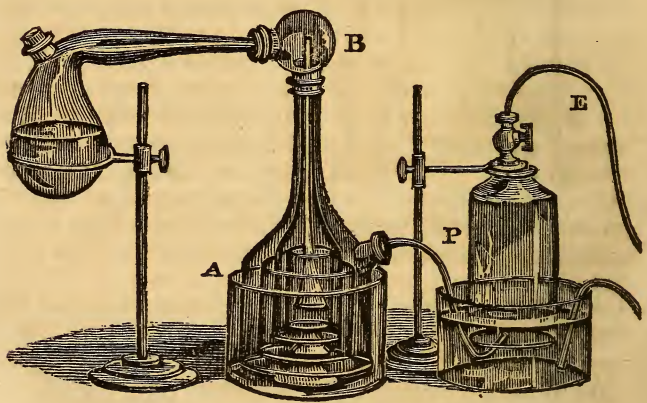
What is said of the carbonate of barytes?

Of the carbonate of ammonia?

What is said respecting the general characteristics of the genus chlorates?

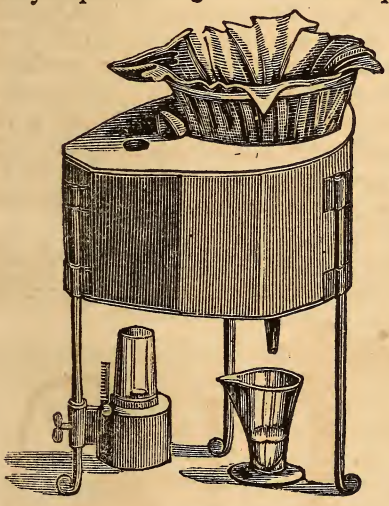
We shall mention but one species under this genus. *Chlorate of potash*, when thrown upon burning coals, parts with the oxygen of its acid and of its oxide, and becomes *chloride of potassium;* on account of parting with so much oxygen this substance has a powerful effect on combustion. When mixed with sulphur or any resinous body, it will inflame and burn spontaneously. Allumetts, or matches, are made of little sticks of pine, the ends of which, are coated with a kind of paste, formed of chlorate of potash and resin; on being lightly plunged into a little vial of sulphuric acid, fire bursts forth. This chlorate enters into the composition of most of that kind of substances called *fulminating* powders, on account of the noise produced in their explosion; Carbon, sulphur, and phosphorus are used with it in these compositions. Attempts have been made to use chlorate of potash in gun powder, but it is found to be so sudden in its operation as to render it a very dangerous instrument to the operater.

This salt is obtained by *saturating a solution of sulphate of potash with chlorine gas.* The figure repre-



Describe the chlorate of potash.

sents a part of the apparatus used for this purpose. *A* is the outer one of three jars filled with a solution of sulphate of potash. The retort contains the oxide of manganese upon which muriatic acid being poured, chlorine gas is disengaged and passes through the neck of the retort to the ball *B*, and from the trumpet shaped tube into the liquid of the inner jar, after saturating the liquid in all the jars, the gas which is not absorbed escapes through the pipe *P*. The pipe *E*, conducts off any superfluous gas into vessels prepared to receive it.

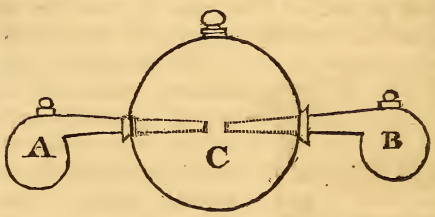


The saturated solution of chlorate of potash must be crystalized in order to obtain the salt in its purest state. The figure represents the manner of doing this. The solution requires to be filtered or strained and this must be done while it is hot. For this purpose Dr. Hare contrived a large vessel of sheet tin containing an aperture for a funnel, and another to serve the purpose of a chimney by conducting off the smoke of the lamp below. This lamp keeps the water hot with which the tin vessel is filled; the hot water surrounding the solution to be strained, prevents its cooling. A coarse fibrous paper is laid into the funnel for the solution to filter through; it is received in the decanting jar beneath, and there crystallizes in beautiful, silvery white plates.

By what method is the chlorate of potash obtained?
How are crystals of chlorate of potash obtained?

Hydro-chlorates differ from chlorates in being formed with *hydro-chloric* acid, (muriatic acid,) instead of chloric acid. These substances were called *muriates* before the discovery of chlorine.

The *hydro-chlorate of ammonia*, or muriate of ammonia, is the salt usually called *sal-ammoniac;* it may be formed by mingling, in equal volumes, in a dry glass vessel, the two gases, ammonia and muriatic acid. Thus A and B represent bottles containing the two gases, and C the glass bottle in which solid muriate or hydro-chlorate of ammonia, being formed by their union, is precipitated in snow white vapours.



The *hydro-chlorate of soda* (or muriate of soda) is common salt in solution; the manner in which it differs from the chloride of sodium has been already explained in treating of that substance.

III. Genus Nitrates. There are only four nitrates found in nature, those of potash, lime, soda, and magnesia. They are found in solution, in water in the earth of old cellars, and under the floors of stables. The most important species of this genus are

1. *Nitrate of potash* or *salt-petre;* this has been already noticed under the head of potash. The nitrates resemble chlorates in many of their properties, particularly in easily parting with oxygen, which renders them impor-

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How do hydro-chlorates differ from chlorates, and what were they formerly called?

How is the hydro-chlorate or muriate of ammonia obtained?

What is the hydro-chlorate of soda?

How many nitrates are there and how do they exist in nature?

What is said of the nitrate of potash?

tant agents in fulminating or detonating powders. The nitrate of potash is an important constituent of gunpowder. It is of general use in putting up meat for salting, through the fibres of which it penetrates giving it a fine, red colour, and aiding in its preservation.

2. *Nitrate of bismuth* has been mentioned as being the basis of pearl powder.

3. *Nitrate of soda* is found in beds of a mile or two in length in South America, and in smaller quantities in other parts of the world, generally in connexion with nitre, or, as it is more commonly called salt petre.

4. *Nitrate of silver*, also called *lunar caustic.* It is very powerful in its effects in disorganizing animal substances; for this reason it is used to remove warts and other excresences; it does this by a slow burning, oxygen leaving its old combination unites with the animal fibre, and thus decomposes it. The nitrate of silver is used in a weak solution for dyeing the hair black, it is also used for indelible ink. Nitric acid forms nitrates with most of the alkalies and the metals, but those which we have mentioned are the most important.

IV. Genus Phosphates; these are salts arising from the combination of phosphoric acid with different bases. Its most important *species* are, 1. *phosphate of lime*, which forms an important part of the bones of animals, and is used in the manufacture of phosphorus: 2. Phosphate of cobalt, by calcining with alum, forms a beautiful colour, called, after its discoverer, Thenard's blue.

V. Genus Sulphates; none of the acids has a stronger tendency to unite with other substances than the sulphuric; for this reason, the genus, sulphates contains many species.

Of the nitrate of bismuth?
Of the nitrate of soda?
Of the nitrate of silver?
What is said of the genus phosphates, and which are its most important species?
What is said respecting the genus, sulphates?

1. *Sulphate of lime, plaster of Paris* or *gypsum* was at first used in the vicinity of Paris; it is found common in various parts of the earth, sometimes in crystals, when it is called *selenite*, sometimes in large, rough masses, this is called *plaster-stone.* The many busts and other ornaments, resembling marble, which are now so common, are made of a pure and white plaster; it is used under the name of *stucco*, to give to the outsides of buildings the appearance of marble, and is very useful as a manure, to promote the growth of vegetation. It is said that after Dr. Franklin's residence in France, where he had witnessed the effects of plaster in promoting vegetation, he wished to introduce its use into his own country. But the farmers believing that they knew better how to raise crops than he did, refused to follow his advice. Dr. Franklin was not accustomed to give way to discouragements, when he had a good object in view, and accordingly he caused a field to be prepared in the common way; but in the middle of the field he wrote with plaster these words—*Effects of Plaster*, and then sowed the whole with grass seed. The grass soon appeared, and that which had been sown upon the plaster, far exceeded the rest in vigour and height. The Doctor then invited the farmers to go into his meadow; astonished with this indisputable evidence of its utility, they all hastened to enrich their fields with plaster manure.

2. *Sulphate of magnesia* exists in solution in the waters of Epsom and Seidlitz springs in Europe; from whence it is commonly called *Epsom salts.*

3. *Sulphate of Soda* was first introduced into medicine by a physician of the name of *Glauber;* from this circumstance it is called *Glauber's salts.*

4. *Sulphate of potash* is used in medicine; it was formerly called *vitriolated tartar*, and its composition considered an important secret.

What is said of sulphate of lime? Of sulphate of magnesia? Of sulphate of soda? Of sulphate of potash?

5. *Sulphate of copper* is commonly called *blue vitriol;* it is found in a state of solution in copper mines.

6. *Sulphate of iron* is called copperas, and sometimes green vitriol; this is important in the arts, especially in dyeing. Ink powder is made with this sulphate and a vegetable substance called nut-galls.

7. Double *sulphate of alumine and potash.* This, though not strictly belonging to the genus sulphates, we shall here mention; it is the well known substance, *alum.* It is composed of 3 parts of the sulphate of alumine, 174
added to 1 part of the sulphate of potash, 88

making the equivalent number of alum, 262

The peculiar taste of alum is well known. It may be dissolved in boiling water. Beautiful large crystals for baskets and other ornamental work, may be obtained by evaporating its solutions. It is of great importance to the dyer in fixing those colours that are soluble in water.

VI. Genus Chromates are composed of chromic acid with alkaline and metallic bases. All these salts are coloured, and many of them are valuable in the arts of dyeing and painting.

Species 1. *Chromate of lead* is a brilliant yellow, sometimes called *chrome yellow.*

2. *Chromate of silver* is of a deep purple colour.

3. *Chromate of potash* is of a lemon yellow colour, and when melted it becomes green. It is used in calico printing, in painting, and in the preparation of chloric acid.

We have now given an outline of the principal salts known in Chemistry, with the exception of some important ones which are formed in part, or entirely of

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What is said of sulphate of copper? Of sulphate of iron?
Describe the double sulphate of alumine and potash.
What is said of chromates?
Describe the species of this genus which are mentioned.
What remark closes this chapter?

vegetable compounds. But we could only notice, comparatively, few of the whole number now known to chemists, exceeding, it is said, more than a thousand. You have seen something of the wonderful manner in which a few elements are made to unite, and form an almost infinite variety of substances. Thus it is in reviewing the works of God, we are ever ready to exclaim, how simple, and yet how grand!

CHAPTER XXIII.

Organic Chemistry. Vegetable Chemistry. Vegetable Acids. Vegetable Alkalies. Oils, &c.

We have completed our view of Chemistry so far as relates to the mineral kingdom, under which we include the water and air as well as stones, earths, and metals. The term *inorganic*, is applied to every thing in nature which is not animal or vegetable.

Two great divisions may properly be made in Chemistry, viz.: of inorganic and *organic* Chemistry; we shall now briefly examine the latter. Vegetables and animals are called *organic*, because they are com-

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What is included under the mineral kingdom?
What two divisions may be made in chemistry?
Why are vegetables and animals called organic, and other objects in nature inorganic?

posed of parts or organs which are connected and mutually dependant on each other; the remaining objects in nature are called *inorganic*, because they do not consist of such parts, but every portion is a perfect specimen of its kind; and except in the case of crystals, which have a regular figure, they are shapeless masses of inert matter.

We have found in the progress of our study of what elements these inorganic substances are composed; the chemist, availing himself of this knowledge, is able to recompose many of them, or put them together after he has once destroyed their composition by analysis.

The chemist is able to separate from their combination the elements which compose animals and plants. He can tell us of what they are made, but he cannot put them together again, to make an animal or a plant; not even a weed, or the meanest worm that crawls, can be imitated by man in one respect, and that the one of all others which makes it what it is, a *living* thing.

The *living principle* both in plants and animals is concealed from the search of man, although he has been prying into the mystery ever since satan tempted our first parents to disobey God, saying, 'thou shalt not surely die.' Their limbs were then active, the warm current flowed in their veins, and they doubtless thought that these were properties of their bodies which could not be taken from them. But God commands, and plants and animals flourish in vigour and beauty; he says, let life depart, and they die and return to the dust from whence they came.

All that can be done in organic Chemistry is to examine, by means of chemical analysis, the elements of which bodies are composed, and to learn the various combinations which exist in animal and vegetable sub-

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Can the chemist recompose inorganic compounds?
Can he create animals and plants?
What constitutes the living principle in organic beings?
What can be done in organic chemistry?

stances. Of these substances new compounds have been formed, which have proved of great importance in the arts, and especially in medicine.

Organic Chemistry is divided into Vegetable and Animal Chemistry.

Ultimate Elements of Vegetables.

Organic substances when analyzed, are found to contain carbon, oxygen, hydrogen, sulphur, silex, the oxide of iron, soda, magnesia, and chalk. Iodine and bromine are obtained from sea weeds. Nitrogen is found in few plants, though it was formerly thought peculiar to animal and mineral substances.

The *ultimate elements* of organic substances, such as carbon, oxygen, &c., are obtained by what is called *destructive distillation;* that is, submitting the vegetable matter to the action of heat in close vessels, and collecting all the products. Oxygen, carbon, and hydrogen form the most important ultimate elements of plants, although other substances are often found at their last or *ultimate* analysis. We shall not attempt to explain to the beginner the complicated process of analyzing organic substances, which is so delicate, that little progress has hitherto been made in this department, in comparison to what might have been expected from the discoveries in inorganic Chemistry.

Proximate principles are produced by plants and animals in their living state; these are gums, resins, honey, sugar, &c., besides various animal products.

The ultimate elements of organic bodies are the same as those we have already examined under inorganic

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How is organic chemistry divided?

What are organic substances composed of?

How are their ultimate elements obtained, and which are the most important?

What are proximate principles?

Do the ultimate elements of organic bodies differ from those of inorganic bodies?

Chemistry. Plants are nourished by inorganic bodies, as the air, earth, and water. Animals feed on plants, and upon other animals which have gained their subsistence from plants.

It is wonderful that of so few elements, such a variety of combinations are produced; in organic bodies, but few of the elementary substances which exist in nature are employed. A slight difference in the *proportions* of the elements, or *in the manner in which they are put together or combined*, seems to produce all this variety.

Organized bodies are distinguished from inorganic by the following characters.

1. Composed of the same elements, but in different proportions.
2. Decomposed, in general, by a lower degree of heat.
3. Cannot be produced by art.

VEGETABLE CHEMISTRY.

Proximate Principles of Plants.

The proximate principles of plants are distinguished into two classes.

Class 1. contains such principles as carbon, oxygen, and hydrogen, without any nitrogen. This class is divided into three orders.

1. Where oxygen is in excess; these are *acids.*
2. Where hydrogen is in excess; these are *resins, oils, alcohol, &c.*
3. Where oxygen and hydrogen exist in the same proportions as in water; these are *gums, sugar, &c.*

What produces the variety which exists in organic substances, when so few elements are employed?

In what particulars are organic substances different from inorganic?

What elements compose the first class of proximate principles?

What are the orders of this class?

Class II. contains such principles as are composed of the elements of the first class, with the addition of nitrogen; this class includes vegetable alkalies. We can do little more than name a few of these proximate principles.

Class I.—*Order* 1. Vegetable acids.

Acetic acid exists in the sap of some plants and is the acidifying principle of vinegar. With various bases it forms *acetates*. *Acetate of lead* is the *sugar of lead; acetate of copper is verdigris.*

Oxalic acid is usually obtained from wood-sorrel, known in botany as belonging to the genus *oxalis;* it exists in several other plants. It is a powerful acid, and a fatal poison.

Tartaric acid is obtained from the tamarind, the grape, and several other acid fruits; combined with potash, it forms *cream* of tartar which is a tartrate of potash. Rochelle salt is a tartrate of potash and soda.

Citric acid, is so called from the genus *citrus*, the lemon or orange, from which it is obtained. This often constitutes one of the powders sold under the name of soda powders, which consist of one paper of an acid, and another of an alkali, usually carbonate of soda. The effervesence is caused by the escape of the carbonic acid, as the alkali unites to the new acid. Citric acid removes iron stains, though not as readily as oxalic acid.

Malic acid from *malus*, the genus of the apple; it is found in many other fruits, as currants, strawberries, &c. The flavor of fruits is chiefly owing to the citric, tartaric and malic acids which they contain.

Gallic acid is obtained from *nut galls*, which grow upon the oak in consequence of the puncture of an insect that often deposites its eggs in the spot, and is therefore found in the centre of the nut. Gallic acid ex-

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What element does the second class of principles contain that does not exist in the first class?

What is said of acetic acid? Of oxalic acid? Of tartaric acid? Of citric acid? Of malic acid? Of gallic acid?

ists in white oak bark, with another principle called tannin. This acid turns iron black; it is contained in tea. If you drop strong tea upon a knife, you will see a black spot upon the place. Gallic acid with tannin and sulphate of iron forms ink and black dyes. The tannin unites with the sulphuric acid of the sulphate, and the iron is precipitated by the gallic acid in the form of a *gallate* of iron.

Benzoic acid is obtained from a gum called *benzoin*, the product of a plant whose botanical name is *styrax benzoin;* it is supposed to exist in the sweet-scented-vernal grass, (*anthoxanthum odoratum.*) It is used in the preparation of the paregoric elixir, and gives it a peculiar aromatic taste and smell.

Kinic or quinic acid exists in peruvian bark, known in medicine as the *cinchona bark.* It is said to be formed of two equivalents of carbon, 12, four of hydrogen, 4, and three of oxygen, 24, this would make 40 its representative number. *Indigotic* acid is obtained from indigo.

Prussic acid is obtained from peach meats and blossoms, bitter almonds, laurel, &c. It is now generally known in Chemistry as *hydro-cyanic* acid.

Order 2. *of proximate principles* contain such as have *hydrogen in excess*, as oils, resins, &c.

Oils are known by a greasy touch, by being easily inflamed, and by not uniting with water, unless through the medium of an alkaline substance.

Oils are of two classes, *fixed* and *volatile;* the former make grease spots on paper, as olive or sweet oil; the latter fly off and leave no stain, as the oil of peppermint, of cloves, &c.

Fixed oils are usually obtained from the seeds of plants. Olive oil is pressed from the pulp of the olive berry

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What is said of benzoic acid? Of kinic acid? Of prussic acid?
What principles does the second order of the first class contain?
What are some of the properties of oils?
What two kinds of oils are there?

which is of the size of a small plum. The oil of *flax-seed* called *linseed* * oil dries without losing its transparency; this renders it valuable to painters, being used not only in house painting, but in nicer colouring of the limner. Oils which like linseed, dry rapidly the air are called *drying oils.* They combine with oxygen while drying, and much latent caloric is brought into a free state;—if light combustibles, such as cotton or flax are wet with these oils there is danger of spontaneous combustion—this is one cause of the frequent burning of cotton and other manufactories. The kernels of walnuts and butternuts, on being heated and pressed, afford oil; beech nuts and sunflower seeds are rich in the product. Palm and castor oil are used in medicine.

Volatile oils give to plants their odour; they are found in blossoms, fruit, leaves, barks, and roots, and are obtained by distilling them with water; the common still is used for this purpose. The water and oil both flow into a vessel such as is here represented; the water having reached the level *a*, *b*, runs off by the spout *c*; and the oil being lighter, floats upon its surface in the space *d*. These oils are reduced by being mixed with alcohol, they are then called *essences.* The oil of turpentine is the most important of these substances; it is much used in varnishing and in medicine. The oil of cloves is much recommended as a cure for the tooth ache; the oil of aniseseed, of pepperment, of nutmeg,

* The botanical name of flax is *linum* from *lin* a thread; from this comes *linseed.*

Describe fixed oils, and mention the most important of them.

What is said of volatile oils, and which are some of the most important?

cinnamon, &c., are used in medicine, and by the housekeeper instead of the spices from which some of them are made. The oils are so powerful that one or two drops contain more of the real aroma of the plant than twenty or thirty drops of the essences.

Camphor is classed among volatile oils; it is mostly obtained from Borneo and Sumatra, where it is extracted from the leaves of a large tree. In Japan it is found in the roots, branches and leaves of the *Laurus Camphora.* Camphor cannot be dissolved in water. Alcohol, or spirits containing it, are the best solvents for camphor.

Resins are the dried juices of plants: they are of various kinds. *Gum resins;* among these are the yellow substance used in painting and medicine called gamboge; it is the juice of the gamboge tree, called in botany the *Stalagmitis gambogoides,* from the the Greek *stalagmos,* a droping or distillation, because the gum escapes in this manner. It grows in Gambaja in the East Indies. Aloes, myrrh, and Indian rubber belong to the gum resins. Indian rubber called also *caoutchouc* * or gum elastic is the resinous product of a tree found in hot countries. On exposure to the air it becomes brown like leather; it can neither be dissolved by water or alcohol. *Wax* is obtained by bees from the pollen of flowers. The bay-berry plant † which grows in sandy plains in the United States, near the sea shore, furnishes a kind of wax of a beautiful green colour, called by housekeepers bay-berry-tallow and used by them to mix with common tallow for candles. The vegetable wax makes them harder and gives them a fine clear appearance.

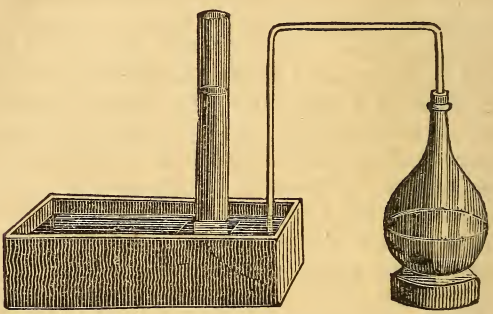
* Pronounced ka-ot-chok.

† Called in botany *myrica cerifera;* the specific name *cerifera* means bearing wax.

What can you say of camphor?

What are resins, and which are some of the most important gum-resins?

Alcohol is not a product of nature but is formed by the fermentation * of certain vegetable juices. It is the intoxicating principle of liquors. If a mixture of one part



of sugar, four of water, and a little yeast, be subjected to a suitable degree of warmth, the fermenting process begins, and carbonic acid gas may be collected; the figure shows the flask containing the fermenting materials, and the receiver inverted over water into which the gas passes. In this process, carbon and oxygen forming the carbonic acid have been given off. Spiritous liquor is obtained by the distillation of fermented liquors. Spirits of wine or pure alcohol differs from wine, brandy or rum, only in being more thoroughly distilled. It is highly inflammable—many instances are recorded of the bodies of persons accustomed to the free use of alcohol or spirituous liquors burning, by taking fire internally. Though such cases of sudden spontaneous combustion are rare, yet every one, who, for a length of time indulges freely in the use of alcohol, experiences a slow combustion of the vitals and destruction of the mental powers.

* For information respecting the various kinds of fermentation see Dictionary of Chemistry, pages 214, 215 and 216.

What is said of alcohol?

It is useful in medicine, and is the only liquid which will dissolve many substances. Wine, cider and ale contain alcohol combined with other vegetable principles and are therefore less intoxicating than brandy in proportion to the alcohol which each contain; in the latter the alcohol is combined with water only, and thus acts directly upon the system.

Ether is a term derived from the Greek *æther*, and signifies spirit. It is a liquor obtained by distilling alcohol with a strong acid; its properties, must of course be very active. It is a powerful agent in medicine, and in Chemistry affords many striking experiments. On account of its volatile nature, when exposed to the air it flies off in a gaseous form, and takes caloric from surrounding bodies. Sulphuric ether, which is obtained by distilling sulphuric acid with alcohol, is that which is in common use.

Order 3. *Contains such principles, as have oxygen and hydrogen in the same proportions as they exist in water.*

Sugar is contained in ripe fruits, and in the sap of many trees and other plants, but is made in the United States, chiefly, from the sap of the maple. It has been made from beets, from the juice of cornstalks and grapes. Most of the sugar of commerce is made from the sugar cane, a plant which flourishes only in warm countries. Sugar is made by boiling and evaporating the juice of the sugar cane or other substance; when properly made it is obtained in imperfect crystals. *Molasses* is the thick juice which runs off when the sugar is drained; it is called *treacle*. When exposed to the action of heat, sugar swells and diffuses a peculiar smell; a large quantity of carbon remains after its combustion.

Starch is a very abundant vegetable product; it exists

What is ether, how obtained, and what are some of its properties?

What principles does the third order contain?

What is said of sugar and molasses?

in the seeds, roots, and stems of plants. For domestic uses it is obtained from wheat, potatoes or Indian corn. Among farmers in the country, it is very common for each family to manufacture their own starch. The green ears of Indian corn or potatoes are grated into large tubs of water; the starch settles at the bottom: the water is then poured off, a fresh quantity of pure water added, and the starch broken up and again mixed with the water; it is then allowed to settle again. The process is repeated until the starch is perfectly clean and white; it is then laid on large platters and dried in the sun. There are now many starch manufactories; near Utica is a village where the business is extensively carried on. Under the name of Poland starch, much that is made in the United States is sold. Starch is insoluble in cold water; boiling water converts it into a jelly. Iodine gives with starch a blue colour, and its presence in any substance may always be known by this circumstance. *Arrow root, sago and cassava* resemble starch in most of their properties.

Gum is a common proximate principle; it is found upon many of our trees, as the cherry and plum tree. *Gum Arabic* is obtained from the species of a plant called *mimosa*, found in various parts of Africa and in Arabia. These gums differ from the gum-resins, already named, in their constituent principles; the latter contain oil.

Vegetable Alkalies.

Class II. of vegetable principles, contain such, as, in addition to carbon, hydrogen, and oxygen, contain some *nitrogen*. These are *vegetable alkalies*, or *salifiable* bases; that is, they unite with acids to form salts; they turn blue vegetable colours green, and exhibit some

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What is said of gum?

What principles does Class 2d contain?

Where does starch exist, how is it obtained, and what are some of its properties?

other properties of mineral alkalies. Most of them are poisonous. They are of modern discovery, and are now admitted to be among the most important articles in medicine.

Morphia was first described in a manner to gain the notice of chemists in 1816, although it had been discovered by a German, engaged in the preparation of medicine, sometime before this. It is obtained from opium, which is itself the dried juice of the poppy. Morphia is supposed to be that principle in opium which causes sleep. Another alkali, called *narcotine*, is supposed to cause the sickening effects of opium; as acids counteract these effects, citric and acetic acid are combined with it, forming a medicine lately introduced into use, under the name of '*the black drop.*'

Quinine and Cinchonia are alkaline substances, obtained by the analysis of the Cinchonia, or Peruvian bark. The *sulphate of quinine* is much used in medicine.

Strychnine is the poisonous principle of the Bohon Upas tree of the island of Java, which is said to infect the air around it. This principle is found in some other plants.

Emetine is extracted from a plant, called *ipecacuanha*, which grows in Brazil and Peru, and is well known as affording from its root an emetic powder, sometimes called *ipecac.* The emetine is very powerful, as it contains the concentrated energy of the emetic principle.

These peculiar principles seem to be almost as extensive as the vegetable kingdom itself, and discoveries in this part of the field of science are continually made. The peculiar properties of the blood root (*sanguinaria*) are found in its extract *sanguinarine;* of tobacco (*nicotiana*)in *nicotine;* of pepper in *piperine;* and *polenin* is obtained from the pollen of plants; it is very combustible, and putrefies in the air.

What can you say of morphia? Of quinine? Of strychnine? Of emetine?

Do these peculiar vegetable principles seem to be extensive in nature?

The last division of vegetable principles, contains such as *are not included under any particular class.* There are some vegetable principles, that have not been analyzed with sufficient accuracy to enable chemists to class them in relation to their elements.

Colouring matter. The vegetable kingdom is rich in colouring matter; every young girl knows that saffron makes a fine yellow, and the leaves of one species of balm a beautiful red; and most housekeepers in the country know that butternut bark affords a brown colour, and maple bark with copperas (sulphate of iron) furnishes a good black.

Dyeing depends on a *chemical affinity* between the colouring matter and the fibres of the thing to be coloured. Wool receives colour the most readily of any substance; next to this is silk.

Most colours require the agency of something to fix them firmly, or they will be destroyed by washing. These intermediate agents are called *mordants*, from *mordeo*, to bite, as it was imagined that they corroded or eat into the fibres of the substance to be coloured; they are also called bases. Among the mordants used in dyeing are alum, copperas, and the oxides of tin and iron. These not only fix the colours, but often give them a brighter hue and a different shade.

The most important colours in dyeing are blue, red, yellow, and black.

Blue is chiefly obtained from a plant called *Indigo;* it is cultivated in India, from whence it was first imported into Europe; it is also cultivated in South Amer-

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Have the elements of all the vegetable principles been examined?

Are there vegetable dyes?

On what principle does dyeing depend, and what substances receive colour most readily?

What are mordants, and which among them are most useful?

Which are the most important colours?

What is blue chiefly obtained from?

ica, and in the southern United States. The botanical name of the plant is *Indigofera;* of this genus there are several species.

Red dyes are made from *logwood*, which grows in South America; *madder*, the root of a plant; *safflower*, the flower of a plant which grows near the Mediteranean and from which *rouge** is made; *litmus*, a lichen plant, and *cochineal*, which is an animal substance, viz. a small insect that affords a rich carmine.

Yellow is obtained from the American *sumach*, from *turmeric*, the root of an East Indian plant, *saffron*,† *anotta*, the seeds of a plant which grows in Cayenne and which is improperly called *otter*, and from some other substances.

Black dyes are made like writing ink, of a compound consisting of the *oxide of iron*, *gallic acid*, and *tannin; logwood* is also used. All the variety of shades of colours is produced by combining the different substances which have been mentioned.

Tannin. We have mentioned this principle, and will here observe that, as its name would indicate, it is of important use in tanning leather. Those who have observed the vats of tanners, know that they contain large quantities of ground bark, of oak, hemlock, chesnut, &c.; this bark contains the astringent principle tannin, which has a great affinity for gelatine, a substance which is abundantly contained in the skins of animals, and with which it forms a tough, insoluble compound, called leather. Gall nuts and the barks of most trees contain tannin; it exists in tea with gallic acid. With

* Pronounced *rooje*, the j soft.

† The saffron, so called commonly, among us, is a compound flower, and not the true saffron, which belongs to the genus *crocus*, of the third class of Linnæus.

What are red dyes made from?
What is yellow obtained from?
How are black dyes made?
What can you say respecting tannin, its use, properties, &c.

the peroxide of iron, tannin forms a dark coloured compound, which with the gallate of iron, forms black dyes and writing ink.

Gluten constitutes a large portion of wheat flour; after washing out the starch from flour, gluten remains in the form of a tough, adhesive paste. This substance is very nourishing, and renders wheat superior to other kinds of grain. Yeast makes bread light, on account of the gluten of the flour; the carbonic acid gas in its attempt to escape, becomes entangled in it, and this causes the little cavities which are so numerous in light bread; they were filled with the gas and air. If yeast is put into Indian meal, very little effect is produced, because it contains little or no gluten. Potatoes contain a large quantity of *farina* or starch which is nourishing, and wheat flour a large quantity of gluten; they are therefore well adapted to each other, and good bread may be made by uniting them. Indian meal which is sweet, and favourable in its tendency to promote digestion, may be added to wheat flour in a considerable quantity, and the gluten of the latter with a suitable portion of good yeast, will prove sufficient to make the mass light.

Yeast or *emptins* * is produced during the *vinous fermentation of vegetable substances.* This is a very important article in domestic economy. Every housekeeper who does not live where she may procure yeast at the distillery, or brewery, will be attentive to keep by her a quantity of this article. Its effect in raising bread has been already noticed, under the article, gluten. In warm weather its operation is much more rapid than in cold; the bread becomes light in a few hours, or goes through what is called the *vinous fermentation;* it

*So named from being left at the bottom of beer, and at first called *emptyings.*

Give some account of gluten.

How is yeast produced, what makes bread sour, and how can this be remedied?

then proceeds to the *acid fermentation*, and the lazy housekeeper who made her bread at night finds her dough has soured while she was indulging in her morning nap. But there is for this misfortune a remedy. If a solution of pearlash or the carbonate of potash be kneaded into the dough, the acetic acid will leave the dough and unite with the potash, and carbonic acid (which though possessing some properties in common with acids is not sour,) will diffuse itself in the meshes of the gluten and help to make the bread lighter. But lest this knowledge should encourage carelessness, we will remark, that when dough has gone through this process, although the bread may be lighter, and free from an acid taste, yet it will not be sweet and pleasant as that which has never been soured.

CHAPTER XXIV.

Organic Chemistry.

ANIMAL CHEMISTRY.

We shall not attempt to treat scientifically upon that part of Chemistry which more than any other, baffles the skill of the learned. Physicians and anatomists, search into the different substances which compose the animal frame; they tell us that blood is composed of *albumen*, *fibrin*, *water*, and some *mineral substances*. They examine the contents of the stomach, and find there a sub-

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Is it easy to understand Animal Chemistry?

stance which they call the *gastric juice*, and whose office it is to dissolve the food that is introduced into its region; but the cause of the circulation of the blood, without which life ceases, and the manner in which the gastric juice performs its analysis, no physician or chemist can explain.

The animal system seems to present a wonderful laboratory, where, with only a few simple elements to operate with, a new and peculiar class of substances is composed; and decompositions are carried on upon principles wholly concealed from human observation. Should the great Creator condescend to reason with man, as with his servant of old, might he not say to him, 'behold the cumbrous machinery with which thy operations are performed, and then turn from them to this human frame! Canst thou tell how its breathing is carried on, how the heart has power at every instant to send forth the vital current, which, in ten thousand courses, rushes to every part of the system, and then in new avenues returns to its living fountain? Dost thou know how the lungs perform their part in the curious machinery, conveying to the blood the vital air, and conducting off that which is unfit for farther use?' Man, in the language of Job, must reply, 'I am vile, what shall I answer thee? I know that thou canst do everything.'

Ignorant as we are, and must be, respecting the complicated machinery of the living body, much may be learned respecting the action of different substances upon the animal system. The physician observes the effect of different medicines; like the chemist, he makes his experiments, but while the chemist in controlling inert matter always produces the same effects, the physician often finds his efforts defeated, and his most powerful medicines fail.

What is remarked of the wonderful machinery of the animal system?

What is said of the difference between the experiments of the physician and the chemist?

The human stomach, and the whole human frame, though partaking of a common nature with inorganic matter, are yet controlled by a power which that does not possess, and whose influence often defeats, or, in an unexpected manner, assists the experiments of the physician. The *mind* is this power—if that is disturbed, the material portion of man is interrupted in its functions. The quick beating of the heart, the throbbing of the temples, the rush of blood to the mantling cheek, or the sudden paleness of the features are often caused by mental excitement—and the mind, as was remarked in our introductory chapter, is no subject for chemical inquiries. It is when mind has left it, that this earthly tenement, may be fully examined and analyzed by the chemist—but then he has nothing before him but matter, and matter hastening to blend with its native inorganic elements.

We will now notice a few of the most important animal substances. The ultimate elements you will recollect are the same as those of vegetables, consisting chiefly of carbon, oxygen and hydrogen—but in animal substances *nitrogen*, which seldom exists in vegetables, is one of the constituents.

The *proximate principles* of animal matter are peculiar to itself, differing from those of plants, not only in the circumstance of their containing nitrogen, but in their rapid decay and putrifaction, during which, they throw off offensive gases.

Gelatine is that soft, jelly like substance which is so abundant in the head and feet of calves. It is this which renders soup nourishing; it may be obtained from almost any kind of meat by boiling it a sufficient time,

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What is said of the power which controls the inorganic matter of which the body is composed?

Are the ultimate elements of animal substances different from those of vegetables?

What is said of the proximate principles of animal matter

What is gelatine, and what are its properties?

cooling it to remove the fat which rises at the top, and straining to separate it from the fibres of the meat. The skins of animals are mostly composed of gelatine. On account of the tough and hard compound which it forms with tannin, skins are made into leather. Glue is made by boiling the skins and other parts of animals, and isinglass is made from fish gelatine.

Fat is an animal product which is used under various forms. *Lard* is the fat of swine, *tallow* of neat cattle; *spermaceti* is the fat found in the head of the whale, *lamp oil* is from the body of the whale. United to potash and other alkalies, all kinds of fat may be converted into soap.

Fibrin forms most of the flesh and muscles of animals. It exists in blood. If with a bundle of twigs or a little brush from a broom some fresh blood be beaten, long reddish filaments will be found adhering to the twigs; this is fibrin, which on being washed in cold water becomes colourless. Its ultimate elements are thus stated by a French chemist.

Carbon	50	parts
Nitrogen	20	"
Oxygen	20	"
Hydrogen	10	"
	100	

Albumen is found in its purest state in the white of an egg, where it exists with water and a little soda. It is also found in a solid state in some parts of the body, and liquid in milk and other animal substances. The facility with which albumen coagulates or hardens, is apparent from the quickness with which the white of an egg cooks in boiling water.

What are the different kinds of animal fat?

Where does fibrin exist, and what are the proportions of its elements?

Where does albumen exist, and for what property is it remarkable?

Blood is composed of water, albumen, fibrin and some salts and oxides. Its colour is supposed to be owing to the oxide of iron. It is a deep purple until oxygen gives it a lively red colour. In breathing there are two processes, the drawing in of the breath called *inspiration*, and the throwing out of the breath called *expiration;* in the former, the air which contains oxygen is inhaled, this mingling with the blood changes it from a dark to a bright red colour, and is carried from the lungs to the heart; in the latter process carbonic acid is thrown from the lungs. You have only to breathe through a tube into a tumbler of lime water, and you will see the evidence that you throw off carbonic acid, in the fact that the lime water acquires a milky appearance as if chalk had been mixed with it; this is in consequence of carbonate of lime being formed by the carbonic acid, from the breath uniting with the lime. Blood on being taken from the veins if suffered to stand for a short time separates into two parts, one thick and dark coloured called the *cruor*, and the upper portion light coloured and watery, called the *serum.*

Milk contains three parts, the *cream* which on account of its being lighter rises to the surface, the *caseous* or cheesy substance and the serum or *whey;* the two latter are separated by means of *rennet.* This is obtained from the stomach of calves, which affords a peculiar substance capable of curdling milk; in which process the cheesy or caseous part is separated from the whey or serum.

Butter is obtained by agitating cream in a vessel called a churn; during this operation the particles of butter unite, and the cream is transformed into *butter* and *buttermilk;* the latter is serum containing caseous or

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Give some account of blood, its composition, the effect of oxygen upon it, the process of breathing, &c.

Of what parts does milk consist?

What takes place during the operation of churning butter?

cheesy particles. Butter has been found to consist of an acid called *butyric acid*, *stearine* and *elaine*, two substances which form the basis of all kinds of fat, and a peculiar substance called *butyrine*.

It is the province of animal Chemistry to explain the nature and constituents of *bones*, *teeth*, *hair*, *wool*, *silk*, *feathers*, *&c.* in short of every substance which either enters into the animal organization, or which is the product of this organization during its active state. Under the latter head are, *saliva*, *tears*, *bile*, *gastric juice*, *&c.* By referring to a Dictionary of Chemistry or to larger works these subjects may be examined by the pupil, who comprehending what has been explained to him, feels a desire for farther information.

We have now, as far as science has penetrated into the composition of the material things which compose the globe, explained to you of *what they are made, and how they are put together.* We have taught you the alphabet of nature, or her simple elements; and shown you that by different combinations of them, all the various substances which the earth presents are formed. You have now learned to understand chemical language. The Beginner in Chemistry who has carefully studied the great laws of affinity, the powerful agency of caloric and electricity in uniting and disuniting substances, the wonderful properties of that all pervading element, oxygen, and the relation of other substances to it; who has traced the combinations of supporters of combustion with combustible bodies, and observed the regular proportions in which they are united, is prepared to understand chemical books and lectures, and to investigate for himself the great volume of nature.

What is buttermilk, and of what parts does butter consist?
What subjects properly belong to animal chemistry?
Repeat the concluding remarks.

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